The Future of the Automobile in Canada

TP 1148

The Future of the Automobile in Canada

Growth, Usage, Energy, Technology, Safety, Environment, Other Modes, and Urban and Inter-city Aspects

Role of the Automobile Study
Strategic Planning Group
Transport Canada

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Glossary

Terms and Units

GNP	=	gross national product i.e. total value at current market prices of all final goods and services produced in exchange for money by a nation's economy before deduction of depreciation.
$	=	1975 Canadian $ unless otherwise specified.
Barrel of oil	=	35 Imperial gallons = 42 United States gallons (now measured in cubic metres, m^3).
Gallon	=	Imperial gallon of gasoline of 150,000 BTU's energy content unless otherwise specified, one gallon of diesel fuel (166,000 BTU's per gallon) being normally converted to 1.1 gallons of gasoline.1 BTU = 1055.06J
BTU	=	British Thermal Unit, the energy required to heat 1 pound of water 1°F.
Household	=	a person or persons occupying a separate dwelling. By definition, the number of households is always equal to the number of occupied dwellings in existence. Since most household heads up to end-century have already been born, it is the most predictable (and also most relevant and dynamic) demographic unit for the study of the automobile (see Chapters 1, 3 and 4).
Energy efficiency	=	vehicle miles per unit of energy (usually the imperial gallon of gasoline) expressed in miles per gallon (m.p.g.).
	=	vehicle km per unit of energy (usually litre of gasoline) expressed in kilometre per litre.
Energy productivity	=	passenger miles per unit of energy (usually the imperial gallon of gasoline) and expressed as passenger miles per gallon (p.m.g.).
AMT	=	automobile miles travelled.
VMT	=	vehicle miles travelled.
Cost-effectiveness	=	a) methods evolved to sum and minimize the total relevant costs of a mode or operation designed to achieve a given purpose or objective.
	or	b) a measure or operation whose effects seem to justify its costs.
	or	c) in a comparative sense, the most cost-effective mode measure or operation is the one that achieves objective or purpose at minimum total costs.
CMA	=	census metro areas consisting of cities with populations more than 100,000 in 1975 — viz. — Victoria, Vancouver, Edmonton, Calgary, Regina, Saskatoon, Winnipeg, Thunder Bay, Sudbury, London, Kitchener, Hamilton, St. Catharines, Toronto, Ottawa-Hull, Montreal, Quebec, Chicoutimi, St. John's, Halifax and Saint John, accounting for 62% of total national households in 1975.
m.p.g.	=	Auto miles per gallon on test basis (simulating urban and rural operation) or actual basis (14% less) when specified.
L/100 km	=	Fuel consumption per 100 km.

Conversions to Metric Units

$°F = \frac{9}{5}(°C + 32)$

$°C = \frac{5}{9}(°F - 32)$

1 Imperial gallon = 4.546 litres

1 litre = 0.22 Imperial gallon

1 mile = 1.609 kilometres

1 kilometre = 0.621 miles

1 mile per gallon = 0.35 kilometres per litre

1 litre per kilometre = 0.286 kilometres per litre

Miles per gallon = 286/litres per 100 kilometres

Litres per 100 kilometres = 286/miles per gallon

Preface

The automobile has been evolving for over 70 years and has now become the dominant passenger transport mode in Canada. At the same time, there are still many facts and factors about its evolution, ownership, use, and inter-relationships with other modes and matters which are not widely known and understood. In particular, in recent years, there has been concern about the role of the automobile in relation to energy and other possible future problems that have emerged in this decade.

These and other important questions prompted the Strategic Planning Group of Transport Canada to undertake an appraisal of the role of the automobile in Canada. The main purpose of the study was to provide information, stimulate informed discussion, and provide a basis for possible actions by governments within their areas of jurisdiction. The Federal roles and interests in the automobile are principally concerned with energy, inter-city multi-modal aspects and specific federal responsibilities for automobile emissions, safety, and fuel consumption.

Recognizing the many interests in the automobile, a special interdepartmental study group was set up to conduct and co-ordinate the work together with technical and steering committees. There was active participation by 9 divisions of Transport Canada, and by the Departments of Industry Trade and Commerce, Regional Economic Expansion, Finance, Fisheries and Environment, Consumer and Corporate Affairs, Energy Mines and Resources and the Ministry of State for Urban Affairs.

Many other resources were used. These include Statistics Canada data (on an extensive scale), consultants, the Economic Council of Canada, the National Research Council, Central Mortgage and Housing Corporation, the Provincial Departments of Transportation in Ontario, Alberta and Quebec, and the municipalities of Ottawa-Carleton, Montreal, Toronto and Calgary. In addition, consultations were held with the automobile, energy and telecommunications industries, and with transportation and energy specialists elsewhere, as well as with other interested and informative people.

The assistance of these departments, consultants, groups and individuals is gratefully acknowledged, and every attempt has been made to digest and synthesize their many contributions, points of view, and judgements into a coherent whole and framework relevant to Canada, its cities and its regions. However, this report does not necessarily represent the views of the Government of Canada or of individual contributors. This is particularly true because complex problems of jurisdiction are involved, and further study by appropriate agencies is required in many of these wide, complex and specialized areas, not least the problems of forecasting futures with confidence in a period of considerable change and uncertainty world-wide.

Chapter 1 —The Growth and Use of the Automobile and its Connection with Urbanization

Growth of Auto Fleet and Use, and Use of Other Modes

Summarizing the development of the automobile, after periods of dominance by water and rail transport, the first period of rapid increase in automobile ownership in Canada occurred during the 1920's until economic depression in the thirties led to stagnation in ownership, and the Second World War to restrictions in production, ownership and use. In 1945, less than 10% of Canadians owned an automobile, although mobility had been greatly improved up to this date by a considerable expansion, surfacing and improvement of the road network (ref. 1). The development of the automobile (and of other passenger modes) in the post-war years since 1950 is summarized in Table 1.1 (ref. 1), its ubiquity, almost instant availability, and lack of labour costs opening out a wide range of activities which are almost entirely auto-dependent.

As suggested by the table, the post-war years established the automobile as the dominant form of passenger transport in Canada. From about 80% of total passenger mileage in Canada in 1950, auto ownership and use increased toward saturation levels (with rapid increase in 2-car households), to account for almost 90% of total passenger mileage in 1975. This growth was attributable to rising real household incomes, household and suburban growth, increasing participation by women in the labour force, and falling real costs of auto ownership and use in relation to other prices and particularly in relation to incomes. This growth in automobile ownership and use has been associated with a general decline in (and increasing subsidization of) the rail and transit modes, although transit use has increased substantially since its low point in 1965, and air travel has increased dramatically, although almost inevitably at diminishing rates of increase.

Although the percentage of car-owning households (and those owning 2 or more cars) has increased rapidly, the situation of the automobile non-user (accounting for some 20% of the nation's households) still causes some concern. Although those groups are expected to decline in percentage terms, they are likely to increase in absolute size, mainly as a result of the growth of the population aged over 65 (ref. 2 and 3). In this non-car-owning category, with much overlapping, are low income families, the elderly, those living alone, single parent families, childless couples and/or families living in large urban areas. To some extent, low income groups in urban areas seem to compensate for the lack of an automobile by living near the centre of large urban areas, and using taxis and transit when required, with a comparatively small burden on their budgets (ref. 4). But potentially, problems of accessibility may remain, particularly in rural areas, in spite of higher auto ownership by low income households than in urban areas, lower living costs, and lower poverty lines (ref. 5).

Table 1.1 Summary Statistics for the Automobile and Other Domestic Passenger Modes 1950-65-75

Item	Year		
	1950	1965	1975
Drivers Licences (millions)	3.40	7.60	11.90
Auto Registrations (millions)	1.90	5.30	8.90
Cars per Head	0.14	0.27	0.38
Car-owning Households	42.00%	75.00%	79.00%
Households with 2 or more Cars	—	12.00%	23.00%
Total Gasoline Consumption (billion gallons)	1.40	4.00	7.00
Traffic Deaths (000's)	2.00*	4.90	6.10
Vehicle Pollution (000's metric tons)	8.10	19.00	15.40
Paved Road Mileage (000's)	25.00	100.00	137.00
Road Expenditures ($ billions)	0.30	1.60	3.80
Automobile Production (000's)	284.00	709.00	1,054.00
Auto Miles Travelled (billions)	17.00	48.00	87.00
Transit Ridership (billions)	1.40	0.90	1.20
Rail Passenger Mileage (billions of rides)	2.80	2.70	1.70
Air Passenger Mileage (billions)	0.50	2.70	9.00
Inter-city Bus Passenger Mileage (billions)	—	—	2.70*

Legend: — not available
* Estimates

Source: *Frayne, A. and A. Chumak, "Perspectives on the Evolution of the Automobile in Canada", Working Paper No. 2, Role of the Automobile Study, Strategic Planning, Transport Canada, 1979.*

Road and Street Mileage and Expenditure, Statistics Canada Catalogue No. 53-201.

The Auto Industry

Several attempts to develop a Canadian automobile manufacturing industry have been made in the last 75 years (ref. 1). All have either failed or led to firms being absorbed into larger units. Today, the bulk of automobile manufacturing is carried out in branch plants of the United States and other producers. In 1965, however, a fundamental shift in the structure of the Canadian industry occurred with the signing of the Canada/United States Automobile Agreement. This established free trade between Canadian assemblers and the United States in new automobiles and their parts, and integration of the North American industry. Prior to this pact, the Canadian industry had been protected by tariffs against U.S. vehicles, but this involved higher prices here than in the United States together with very heavy imports of parts. Among the difficulties faced by Canadian manufacturers in the early sixties were higher costs than parent United States companies, a total production volume of only about 600,000 vehicles annually, and the necessity to import entirely items such as automatic transmissions. By 1964, Canada had an annual trade deficit of over $700 million in automotive products with the United States on annual trade of about $800 million (ref. 1) in current dollars.

After the Auto Agreement was signed,however, there was a considerable increase in Canadian production and employment, total employment in the industry (manufacture and parts) increasing from 69,000 to 108,000 from 1964 to 1974. Today, the auto manufacturing industry contributes approximately 3% of total Canadian GNP. In certain years (1971-73) of the auto pact, Canada even enjoyed a trade surplus with the United States in automotive parts, but this has reversed and a fluctuating overall deficit (sometimes approaching $2 billion annually) on trade of about $20 billion has now developed (ref. 1).

While Canada maintains a proportional share of industry employment and a surplus in new car production and exports, it has captured a less than proportionate share of parts production via à vis the U.S.

Concerning automobile imports from overseas, a somewhat similar situation has developed in that the trends toward smaller cars may have given an advantage to European, Japanese and other manufacturers with more experience in small car production. Thus, overseas imports have absorbed some 20% of the Canadian new car market in recent years, although this might be checked or reversed by further development of North American small car production, and the devaluation of the Canadian and U.S. dollars. Another trend of importance is the development of the "international car" to be produced and sold in many markets.

The Current Use of the Automobile

As part of the role of the automobile study, a small scale study was carried out in 1976 on automobile travel per household (as the most dominant factor in auto trip generation) by trip purpose, mileage, and relevant income group, consisting of 717 interviews in communities of various sizes in Alberta, Nova Scotia, Quebec and Ontario. The study revealed the patterns of automobile mileage by trip purpose given in Table 1.2.

As may be seen from this table, auto travel per household was least from households in CMA areas, and greatest from households in rural areas, with CMA fringe areas and small cities in between. However, it may be noted that the major trip purpose (commuting) tended to decrease with size of city, but rise for rural areas.

By reconciliation with other data, it was possible to estimate total national auto mileage in 1975 as being approximately 87 billion (of which 55% originated in the 22 CMA's). 37% was for commuting, 32% on commercial, personal business, shopping and external business, and 31% on recreation, week-end travel and vacation travel. The estimate of 87 billion auto miles in 1975 was equivalent to annual averages of about 10,000 miles per automobile and about 12,700 auto miles per household. Total expenditures on auto use were some $13 billion in 1975, equal to about $1,460 per automobile, $1,900 per household, and 15c per automobile mile.

From this automobile survey, and from data on other modes, it is possible to build up the total estimated pattern of passenger mileage at an estimated average occupancy of 1.5 persons per automobile in urban areas and 2.5 persons per automobile elsewhere (ref. 7).

Table 1.2 Estimated Average Annual Automobile Mileage Per Household by Area of Origin and Trip Purpose from Automobile Survey* 1976

Area of Origin	Trip Purpose and Annual Auto Mileage Per Household								
	Commuting	Commercial	Personal	Shopping	Business	Daily Recreation	Weekend	Vacation	Total
CMA Core	4,999	764	217	484	717	1,360	1,311	1,262	11,114
%	47	7	2	5	7	13	12	12	100
CMA Fringe	4,500	989	410	851	1,182	1,845	1,666	1,158	12,100
%	36	8	3	7	9	15	13	9	100
Small City	3,219	1,888	1,212	1,195	2,044	1,858	1,077	937	13,430
%	24	14	9	9	15	14	8	7	100
Rural	6,378	949	444	1,154	2,309	2,210	819	1,520	15,783
%	40	6	3	7	15	14	5	10	100

*Based on 717 interviews

Source: Sims, L., I.B.I. Group Affiliate, "Automobile Ownership and Usage in Canada-1976" Working Paper No. 16, Role of the Automobile Study, Strategic Planning, Transport Canada, 1979.

Table 1.3 Estimated Passenger Mileage by Mode, and Areas Where Performed in Canada 1975

Mode, and Area where Performed	Auto Mileage Billions	Passenger Mileage Billions	Percentage of Total Passenger Miles
Automobile inside urban areas	51	75	41
Automobile Inter-city	8	19	10
Automobile Rural	28	71	38
Urban Transit	—	5.3	3
Inter-city Bus	—	2.7	2
Inter-city Rail	—	1.7	1
Inter-city (Domestic) Air	—	9.0	5
Total	87	184	100

Source: Reynolds, D.J., "The Expanding City; the Use of the Auto and Transit in Relation to Urban Growth 1975-2000", Working Paper No. 9, Role of the Automobile Study, Strategic Planning, Transport Canada, 1978.

This table, in allocating auto mileage into trip types and the areas in which performed (about 60% in urban areas) and multiplying by estimated average occupancies, emphasizes the almost complete dominance of the automobile inside urban areas and in rural areas, and for urban/rural trips. However, for inter-city passenger mileage, its share falls to 56%, mainly because of the growing importance of the air mode for longer distance trips. Also, it may be noted that with 184 billion total passenger miles, the average Canadian apparently travelled no less than 8,000 miles domestically in 1975, or an average of 22 miles per day by motorized means.

Table 1.4 shows the importance of household income (itself positively correlated with household size, number of licensed drivers, number of wage earners) as a determinant of car ownership and use, with income elasticity or responsiveness of 1.10. However, there is a tendency for this responsiveness to fall for the higher income groups, as saturation levels of car ownership and use are approached.

The auto trip types most responsive to income (and probably the least essential in terms of auto use) were week-end recreation and commuting, whilst the least responsive trip types (and probably the most essential for auto use) were shopping, vacation and daily recreation.

Urbanization and the Automobile

Since the growth of the automobile has been closely connected with the historical growth of urbanization, it is useful to briefly survey this historic relationship, first generally (ref. 8), and with particular reference to Canada (ref. 7).

General

The modern metropolis is the product of urban growth and of the combined effect of the country-to-city centripetal, and the city-to-suburb centrifugal movements carried by long and short distance transport respectively (ref. 8).

Long distance transport had a decisive influence on the location and function of cities and consequently on their size and rate of growth. It had little direct impact on the form of the city although sometimes modifying it indirectly. Historically, three types of cities evolved: central places that arose in fertile regions and expanded their zone of influence as improvements in transportation overcame the friction of distance; towns which grew at strategic transportation nodes; and specialized cities which arose on the basis of natural resources or social significance. Cities decayed if long distance routes were cut off or competing cities developed newer and more efficient modes of transport, but economically vigorous cities could withstand these changes.

From the earliest centuries, water was vastly superior to land transportation, particularly in Canada. Water and wind were a much more effective source of motive power than wagons or muscle power. This trend was reversed in less than one generation when railroads achieved domination in overland travel,leading to rapid growth and proliferation of new inland cities.

The result of the continuing improvement of long distance transportation by water, rail and recently air (together with agricultural and other techniques) has been an exponentially growing trend towards concentration of jobs, activities and population in ever-larger metropolitan agglomerations. By the late 1800's, modes such as the steamboat, steam railroad and telegraph moved goods, persons and messages all over the globe. Yet within cities of many million inhabitants, all movements still relied on human and animal muscle. Consequently,

Table 1.4 Household Income, Household Characteristics, and Average Auto Mileages per Household, All Canada — 1976

No. in Sample	Household Income $	No. of People in Household	No. of Licenced Drivers	No. of Wage Earners	Autos per Capita	No. of Autos	Average Auto Mileage per Household
25	3,000	1.58	0.84	0.20	0.35	0.56	4,540
36	3,000-5,999	2.07	0.58	0.36	0.22	0.47	2,450
72	6,000-9,999	2.75	1.14	0.94	0.28	0.76	5,828
92	10,000-11,999	3.17	1.25	1.02	0.29	0.92	7,908
122	12,000-14,999	3.56	1.70	1.30	0.37	1.32	13,423
150	15,000-19,999	3.78	2.00	1.56	0.40	1.51	15,248
92	20,000-24,999	4.11	2.20	1.77	0.42	1.72	17,615
86	25,000	3.94	2.49	1.85	0.45	1.77	26,717
Total 675*							

*Excluding 42 that could not be allocated to income ranges.

Source: Working Paper No. 16

with horizontal and vertical growth circumscribed, growth became more compact and extremely high densities resulted.

This urban concentration provided a strong motivation for city dwellers to seek more land. The ensuing city-to-suburb movement and growth was first made possible by the railroad. The 1890 innovation of electric traction brought about streetcars and rapid transit trains. The succeeding predominance of common carriers led to the tentacle shape of the metropolis of the early 1900's. Improved mobility led to decreased density. The growing separation of work and home demanded better transport; and improved transport enabled people to live even farther away from work in larger cities. Densities in the urban core started to decline rapidly in the second half of the nineteenth century, well prior to the advent of the automobile. The bicycle, which appeared in the 1890's, was the first efficient and fairly inexpensive means of individual travel — and the forerunner of the automobile.

The invention of the internal combustion engine and its application to motor vehicles in the early 20th century brought about an unexpected reversal of both the trend toward collective transportation and the previous distinction between modes of long and short distance travel. As urban and inter-urban travel could now be performed by a single ubiquitous mode, it was thought that the importance of the city would decline. However, the attraction of big cities is based on increasing division and specialization of labour and by the growth of highly specialized "higher order" tertiary industries which tend to concentrate even more than secondary industries in the largest centres. In Canada, therefore, metropolitan growth is still vigorous and likely to continue (see Chapter 4).

There is no clear evidence that improvements in urban transport induce city growth in terms of attracting enterprises and households. However, there is no question that internal transport has always had a decisive impact on the *form* of cities. The introduction of the automobile into the urban environment brought about a radical change in urban form, which in turn led to decisive changes in short distance transport. The decrease in overall density of urban areas, which started about 50 years before motorization, was continued in a different pattern. The green wedges between urban fingers were now as accessible as the fingers themselves and were quickly filled with new subdivisions and overall density fell still more (see Figure 1.1).

As the automobile often cut times of given door-to-door trips in half, it quadrupled the area reached within a given time from the urban centre. The benefits of improvements in urban transportation therefore appear to have been taken out not only in the form of less time, but in the form of growth and space as well as of more choice of potential destinations. This tendency leads to the concept of the fixed travel time budget. The total average time spent on travel during the day appears to vary little under widely varying conditions. If people spend most of this fixed travel time budget on travel to work they make few other trips; if the journey to work is short, they make more trips for other purposes. In Canada today, the time spent on travel to work averages only 21 minutes (ref. 7), suggesting that "congestion" may be more due to psychological than to transport reasons. Congestion is ever-present to some extent, appearing on a new facility because trips are now made that were foregone previously due to time constraints, and traffic demand expands with the supply. But cities never seem to have congested themselves to death, and it is indeed difficult to find evidence of serious deterioration in urban traffic speeds (ref. 7).

The automobile has brought about not only a quantitative expansion, but also a qualitative change in urban areas. Prior to the motor age, most secondary and tertiary employment was concentrated in the centre. Then manufacturing and warehousing plants found that they could enjoy the advantage of cheaper land for expansion by establishing themselves anywhere on the periphery, and now the tertiary jobs are also to be found far from the centre. The huge shopping centres are the most spectacular signs of this shift but more and more offices are now locating on the periphery.

The automobile helped to bring about the extension of the urban area at low density and the dispersal of employment and service destinations, these in turn now require the service of the automobile. Transit service requires concentration of trips in space and time. For peak period trips to and from the core, it remains superior to the automobile (see Chapter 4) and in the largest cities caters to a large proportion of such trips. But a common carrier can only work if it carries an adequate number of people in common. This is often precluded by the dispersal of destinations away from the centre, by the growth of dispersed non-work trips, and low density residential areas. As a result greater proportions of urban trips have been made by automobile.

Urbanization, the Automobile and Transit in Canada

In 1871, in the first census after Confederation, Canada (plus Newfoundland) had a population of about 4 million in about 600,000 households. Since that date, the population has increased almost six fold to nearly 23 million in 1975 (ref. 7), while households have increased almost 12 fold to nearly 7 million households, falling in average size from 6.66 to about 3.33 persons. Disregarding fluctuations for wars, booms, and depressions, the numbers of households have roughly doubled every 30 to 35 years, an annual rate of increase of about 2%, while household incomes (again with fluctuations) seem also to have increased at about the same long term rate.

However, the rate of increase in households has been very uneven between urban and rural areas, the latter being defined as any separate area with a population of less than 1,000 in 1 sq. mile.

While the number of households in urban areas (associated with increasing urban employment and incomes) have increased almost 50 fold from 120,000 in 1871 to about 5,700,000 now, the number of households in areas that have *stayed* rural has increased less than 3 fold, from 480,000 in 1871 to about 1,300,000 now. The number of urban households has exceeded those in rural areas since 1921-31.

The national relationships between population, households, automobiles and transit since 1951 are given in Table 1.5. It may be seen from this table that, while households and population (with high birth rates and net immigration) increased at about the same annual rates in the decade 1951-61, birth rates and the rate of population increase have fallen since then. At the same time, the high post-war birth rates have matured into household formation so that the two rates have increasingly diverged. The table also shows that from a rapid rate of increase in the decade 1951-61, the rate of increase in automobiles has fallen toward that in households as saturation levels in the proportion of households owning cars (currently almost 80%) are approached.

Finally, Table 1.5 shows that after peaking at some 1.4 billion urban transit rides in 1950-51, transit use declined fairly rapidly. It stabilized in the 1960's and then increased rapidly after 1971, due to increasing policy emphasis on urban transit and subsidies to expand its services and utilization.

The figures given in Table 1.5 have other important implications. Firstly, they show that household growth has increasingly become the "leader" in urban growth, that forecasts based on population growth are increasingly misleading, and that households should normally be substituted for population in any consideration of future urban growth and auto usage.

Secondly, the figures show that by now, more than half the housing stock and urban fabric of Canada has been built since 1951, during which time the automobile population has quadrupled. Consequently, Canada's growth and development is closely tied up with that of the automobile and it appears that the present housing stock, being fairly new, fixed and durable, will probably be occupied to at least the end of the century,

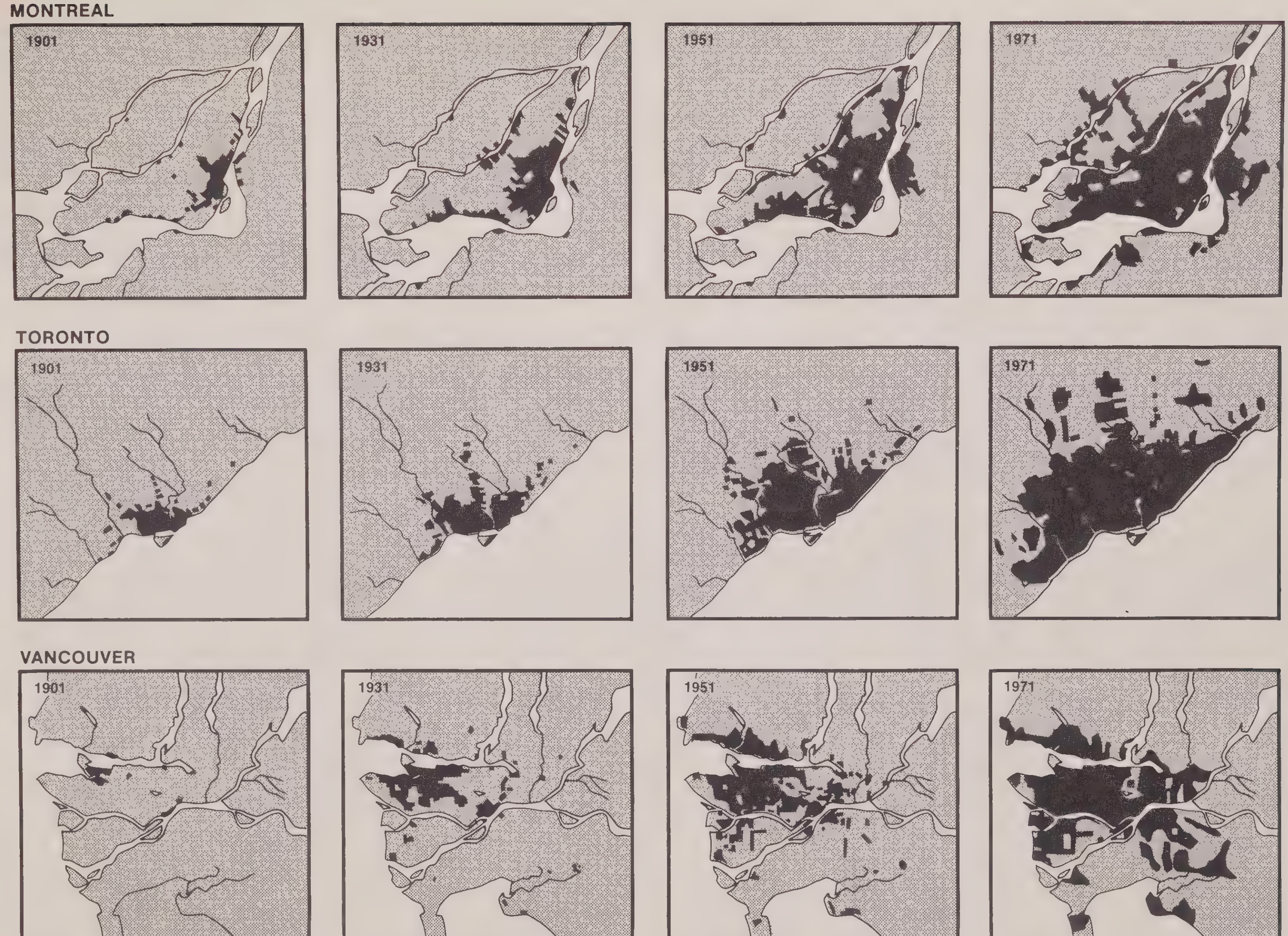


Figure 1.1 Growth of Urbanised Areas of Montreal, Toronto and Vancouver 1901-1971

Source: Perspectives Canada II, Statistics Canada, 1977.

unless it is radically different from households' wants, or radically incompatible with energy problems for heating and transportation.

Thirdly, in conjunction with a near doubling of average real income per household since 1951 (an annual rate of increase of almost 3%), households have traded up to new dwellings. In this urban growth (with net household formation concentrated in the lower age groups), apartments have generally played an increasing part until fairly recently, increasing from 13% of national dwelling completions in 1951 to more than 50% in 1968 and 1969, but falling back gradually to about 34% of completions in 1975, as demand for and supply of single family dwellings increased.

However, in 1976, this reversal seems to have reversed itself, for while total housing starts rose by 18% between 1975-76, apartments increased by 27%, and row housing by 55%, while detached and semi-detached starts increased by only 7%. The trend of urban housing by dwelling type and density seems to have been rather uncertain therefore, tending towards single family dwellings in conditions of higher economic growth, and towards apartments and/or row housing in more difficult circumstances, particularly with falling birth rates, more women working, and smaller households. These trends and their connection with auto trip lengths and use are discussed further in Chapter 4.

Having briefly surveyed the historic growth of the automobile, and its connection with urbanization, housing and other factors, it is possible to attempt to forecast its future role from this base in subsequent chapters.

The general theme and objective will be to determine the roles in which the automobile is the most cost-effective and energy productive mode, that is, able to meet demand or needs at minimum total costs, costs being estimated as fully as possible, with emphasis on energy.

Table 1.5 Population, Households, Automobiles and Urban Transit Use Trends in Canada 1951-1975

Year	Fertility Rate	Annual Average Net Immigration	Total Population (millions) and Annual Rate of Increase %	Total Households (millions) and Annual Rate of Increase %	Total Automobiles (millions) and Annual Rate of Increase %	Urban Transit Usage (billions of rides) and Annual Rate of Increase %
1951	3.50		14.0	3.4	2.1	1.4
		108,000	(2.7)	(2.9)	(7.5)	(-4.0)
1961	3.80		18.2	4.6	4.3	0.94
		72,000	(1.7)	(2.8)	(4.9)	(0.3)
1971	2.19		21.6	6.0	7.0	0.97
		120,000	(1.3)	(3.0)	(4.2)	(4.5)
1975	2.00*		22.8*	6.8*	8.9*	1.16*

*provisional figures

Sources: *Canada Year Book 1975, Statistics Canada.*
1975-76 Transit Fact Book, Canadian Urban Transit Association.
Canadian Housing Statistics 1976, CMHC.

Chapter 2 — The Automobile — Future Energy, Technology, Materials, and Non-Transport Alternatives — 1975-2000

In starting this chapter, it is necessary to point out at the outset that being concerned with forecasting 25 years into the future (to allow for the durability of transport systems and lead times for decisions), this area tends to be dominated by uncertainty, particularly in the matters being considered. Therefore, whilst it is necessary to reach reasonably firm conclusions as far as possible, it is impossible to be dogmatic and accurate in detail, particularly as knowledge is rapidly changing and improving in these controversial areas.

The World Energy and Oil Outlook

Potentially the most critical Canadian energy problem tends to be oil, other Canadian energy sources such as coal, natural gas and electricity being in more ample potential supply, see Figure 2.1. Since oil is also a major world problem, it is useful to start with a study of world oil demand and supply (ref. 9) in the form of a Workshop on Alternative Energy Strategies. Some 70 people from business, industry, government and the universities, from 15 major oil importing countries (including Canada) came together over a 2-year period to study world energy supply and demand, to identify potential problems, and consider strategies to solve these problems, the Union of Soviet Socialist Republics being excluded as a significant unknown in the world outlook.

Summarising their work, it must be stressed that world oil supply and demand result from complex interactions between geology, politics, demographic and economic growth, and prices, in which it is difficult to accept extreme positions ranging from serious pessimism to assumptions that the "market" or "technology" will solve all the problems. In addition, estimates of proven recoverable reserves are uncertain and change from year to year, and the natural tendency seems to be for the outlooks to oscillate between pessimism and optimism.

The world outlook for oil was evolved for two scenarios, high growth (5.2% per annum) assumed high energy prices constant at U.S. $13 per barrel until 1985 and increasing by 50% by 2000. Low growth (3.4% per annum until 1985, 2.8% thereafter) assumed low prices constant at U.S. $13 per barrel. The world demand and supply outlooks are then exemplified by Figures 2.2 to 2.5. They take account of demand and world potential oil availability, the trend of past discoveries and re-assessments of reserves, the potentials for primary, secondary, and tertiary recovery*, the limits to annual production via reserve ratios (1/15**), and possible limits to production from the oil exporting (OPEC) governments.

These estimates show that, with OPEC restrictions, world oil demand could exceed supply by 1980 for the high growth/price/restriction situation (Figure 2.3), and by 1990 for the low growth/price/restriction situation (Figure 2.4). Without OPEC restrictions on supply (dotted curves in Figures 2.2 to 2.5) world oil demand would exceed world oil supply by about 1997 for the high growth and price situation (Figure 2.3) and by 1990 for the low growth/price/situation (Figure 2.4).

The Canadian Energy and Oil Outlook

The Canadian energy and oil outlook naturally has a somewhat different shape and profile to the world outlook. Figure 2.1 was an example of the whole domestic energy supply outlook in Canada (ref. 10), which shows that the major domestic energy supply problem is expected to be in oil, the "assured" domestic supply of which is expected to decline.

The supply of other major energy sources, electricity, coal and gas, is expected to increase, although at higher costs and prices as all energy prices move toward parity with oil (ref. 10). The oil situation is especially important for the automobile since it accounted for some 25% of total Canadian oil consumption in 1975, while oil accounted for about 45% of total Canadian energy supply in 1975, almost all Canadian passenger transport being dependent on oil.

To concentrate on the Canadian oil demand and domestic supply outlook (with warnings on uncertainty outlined above), an illustrative example may be built up as in Figure 2.6 (ref. 11), using the Energy, Mines and Resources (EMR) forecasts contained in "An Energy Strategy for Canada", and extending them to the year 2010. Base demand in Figure 2.6 is based on the EMR high oil price ($13 per barrel by 1980) and low economic growth, GNP being expected to increase by about 4% per annum over the whole period. The conservation demand curve assumes legislative, regulatory and fiscal measures which would reduce energy demand, in particular greater oil conservation in home heating, commerce and industry, and through the achievement of the automobile fuel economy standards given below. This conservation forecast anticipates an annual rate of increase in oil demand of about 1.7% over the period. The supply forecasts in Figure 2.6 are based on NEB forecasts of "producibility"* from established areas from 1975 to 1994, and an assumed further depletion of reserves thereafter, without significant reserve additions. Oil sands "producibility" is expected to grow steadily, whilst the growth of producibility from frontier areas (the most speculative of the supply forecasts) is based on the assumption that three frontier areas (Mackenzie-Beaufort, the Arctic Islands and the East Coast) will yield reserves of 10 billion barrels to about 1994.

In spite of the inevitably speculative nature of the forecasts in this example, it appears (as with most other possible alternative forecasts) that Canadian domestic supply will decline and fail to meet domestic demand in the future, with net oil imports reaching a peak at about 1985, at about the period that international oil demand/supply problems may develop (see Figures 2.2 to 2.5). Net oil imports would peak at about 1 million barrels a day (about 40% of total consumption) for base demand in 1985 (resulting in an oil balance of payments deficit of about $4.7 billion at $13 per barrel), or about 800,000 barrels per day (about 35% of total consumption) for conservation demand in 1985 (for an oil balance of payments deficit of about $3.8 billion). Thereafter (depending on the world price for oil in constant Canadian dollars), the oil balance of payments deficit would tend to decline by end-century (see Chapter 3).

More detailed estimates of oil demand for auto use, and of prices, for more detailed scenarios are given in Chapter 3. However, in spite of the uncertainties, it does appear that the example in Figure 2.6 is broadly representative of the current Canadian oil outlook (see alternative example in Figure 2.7) to be revised as knowledge and expertise change and improve.

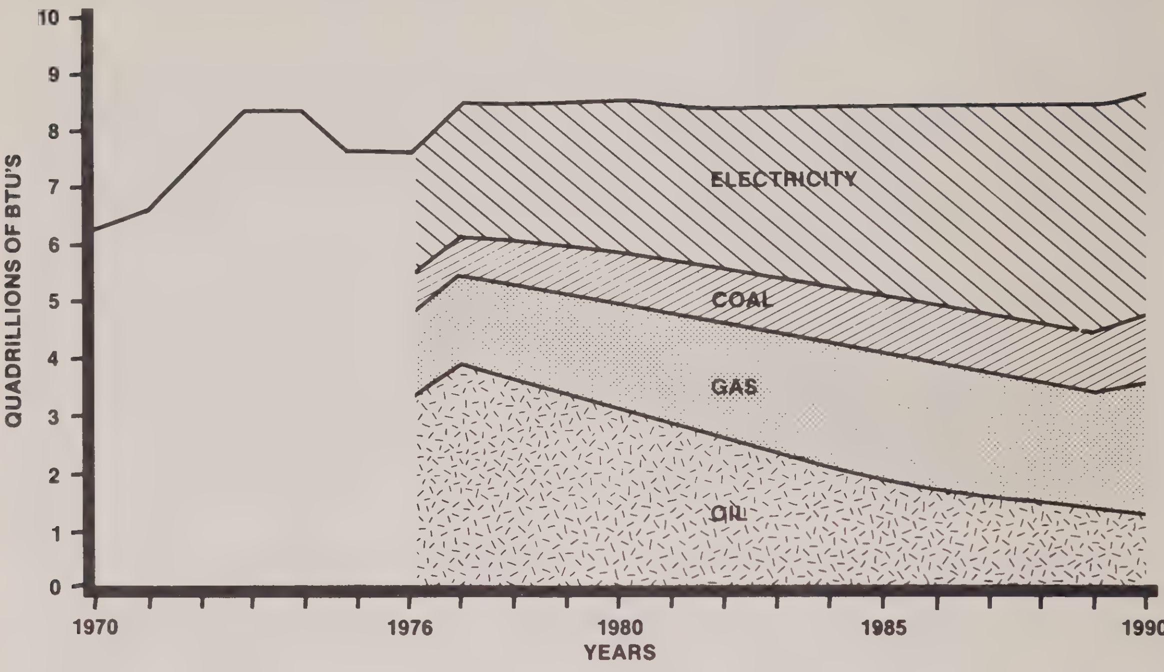
However, the example in Figure 2.6 is heavily dependent on expected yields from the tar sands and frontier areas (or on new discoveries in established areas), or on oil prices higher than $13 per barrel to further encourage conservation, stimulate domestic supply, and thus help close the gaps between the demand and domestic supply curves exemplified in Figure 2.6.

*These are recovery by natural pressure, pumping, and lowered viscosity respectively.

**In general, it seems impossible to recover more than a fraction (1/15) of oil reserves annually without reducing long term supply (ref. 9).

*The maximum ability to produce (irrespective of demand) without reducing long term supply

Figure 2.1 "Assured" Energy Supplies for 1990



Source: Estimates, Department of Energy, Mines and Resources 1977

Future Conventional Automobile Technology and Gasoline Economy

The demand for and consumption of oil by the conventional automotive sector is affected by many interrelated factors which can be grouped into three broad categories, technological (e.g., engines) quasi-technological (for example, broader cut fuels which use greater fractions of crude oil)*, and non-technological factors (such as the vehicle size mix), and mainly determined by market demand and institutional factors (ref. 12).

The technological and quasi-technological factors aimed toward greater conventional fuel economy, may be divided into three categories; engines (with petroleum based fuels), transmissions, and vehicle design. Classifying the potential changes into these three categories and assessing the impact of each category (and the cumulative impact) on auto fuel economy, the results (which are too complex to give in detail) are exemplified in Table 2.1 for a median (intermediate) auto of 4000 pounds with a 1975 actual overall fuel consumption of about 19 m.p.g., in a normal growth situation (see Chapter 3).

This example shows that the greatest advances in fuel economy to be expected by conventional autos will be via engines and vehicle design (with a small contribution from transmissions) to give an estimated 42% cumulative reduction in fuel consumption by end-century, thus increasing average new intermediate auto miles per gallon, for example, from 19 to 33 by end-century.

Again entering the controversies of forecasting (even for conventional automobiles) concerning engines, the most promising developments seem to be, in the near term, the improvement of the conventional (Otto) engine, which is regarded as still a long way from maturity, and in the longer term the further development of the conventional engine, and engines using broader cut or blended fuels (e.g., with methanol*), including the diesel. However, the higher initial cost of the diesel, its poorer acceleration and greater noise and the problems of cold-starting may reduce its acceptance in Canada. But the greater use of engines using broader cut fuels (including diesels) can achieve up to 35% more transportation from a barrel of crude by shifting the heavier fractions of crude toward the automobile, and substituting other energy sources in their markets.

Concerning changes in vehicle design, the most promising development seems to be down-sizing in order to reduce weight and wind resistance, with lesser changes due to the greater use of lighter materials such as plastics and aluminum with the possible development of a small specialized urban car. Together these improvements (in response to fuel economy guidelines and higher gasoline prices) applied to the entire new vehicle *fleet* (on the lines of Table 2.1) might attain for example, actual average new car fuel economy of 30.5 m.p.g. by 1985 (and 33 m.p.g. by 2000) in a normal growth situation, as compared with Transport Canada new auto guidelines of 24 m.p.g. in 1980, and 33 m.p.g. in 1985 based on laboratory test cycles. Other improvements would be obtained by a change toward smaller size classes, and estimates of actual new car and *fleet* fuel economy taking this into account are given in Chapter 3.

Alternative Technologies and Energy Sources for the Automobile

In considering alternative technologies and energy sources for the automobile, it must be made clear that this area is naturally considerably more controversial, subjective and

*Crude oil (depending on origin and grade) may broadly be refined (or cut) into gasoline, heavier oil for heating and diesel, and heavy oils, waxes, etc.

* Also termed methyl alcohol or wood alcohol, and commercially produced by the destructive distillation of wood.

Figures 2.2 — 2.5 Examples of Estimates of World Oil Demand and Supply 1975-2025

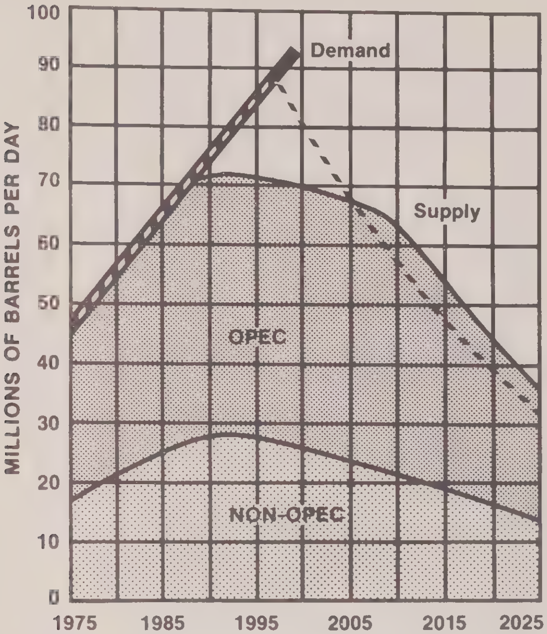


Figure 2.2 High Growth and Price with OPEC limited to 45 million barrels per day

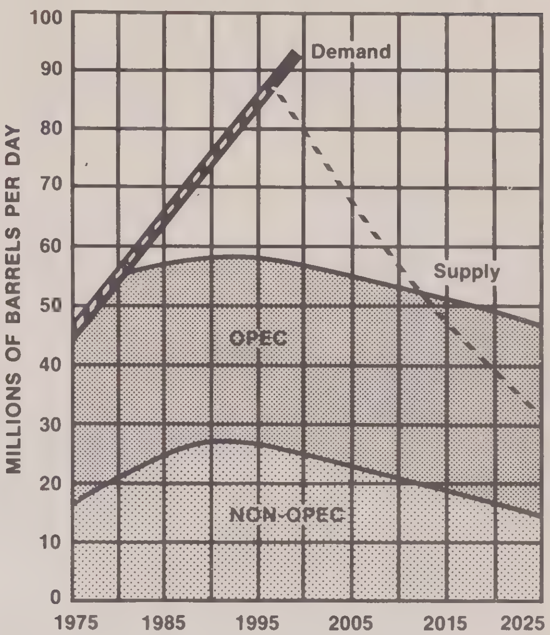


Figure 2.3 High Growth and Price with OPEC limited to 33 million barrels per day

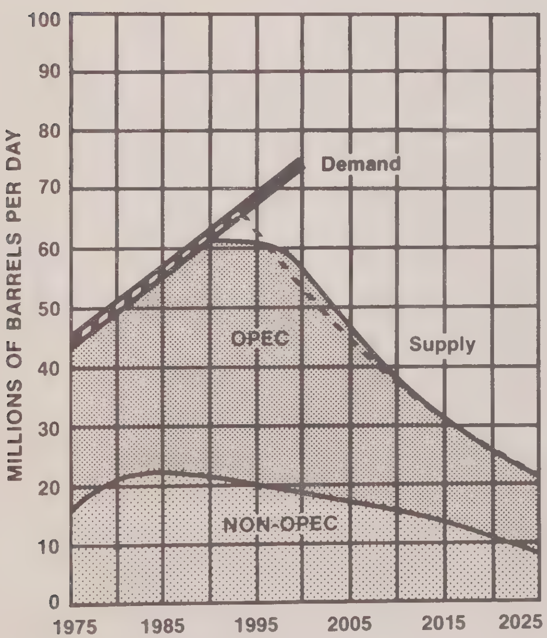


Figure 2.4 Low Growth and Price with OPEC limited to 40 million barrels per day

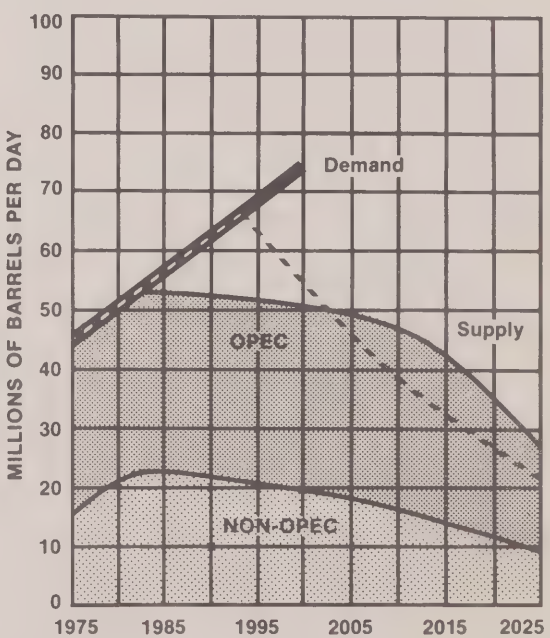
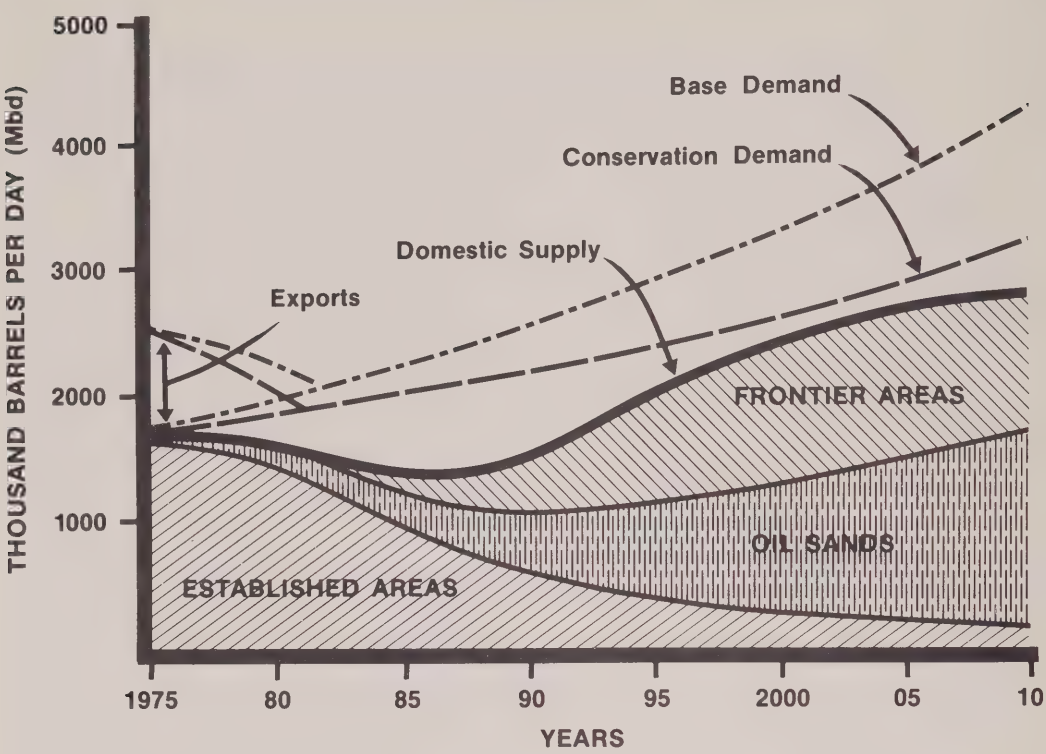


Figure 2.5 Low Growth and Price with OPEC limited to 33 million barrels per day

Figure 2.6 Example of Forecast Canadian Crude Oil Demand and Supply 1975-2010



Sources: Department of Energy, Mines and Resources, An Energy Strategy for Canada, 1976.
Constable, G., Canadian Resourcecon Limited, "Canadian Energy Scenarios: 1975-2010", Working Paper No. 12, Role of the Automobile Study, Strategic Planning, Transport Canada, 1978.

speculative than the development of the conventional automobile, powered by petroleum-based fuels.

However, a technological assessment of alternatives (ref. 13) (without considerations of acceptability in the market place) was carried out on the systems outlined in Figure 2.8, which fall into four groups:

Group 1 — Energy Storage — Single Energy Power Source (e.g., battery)
Group 2 — Energy Storage — Multi-Energy Source (e.g., battery — flywheel)
Group 3 — On-Board Energy Conversion — Multi-Energy Power Source (e.g., heat engine/battery)
Group 4 — On-Board Energy Conversion — Single Energy Source (e.g., fuel cell)

These four groups with 10 alternative systems altogether were assessed against each of 4 criteria to ensure their competitiveness with the conventional automobile — high power/weight, high energy/weight, large cycle life with deep depth of discharge, and low cost/material availability.

Of the 14 battery types assessed against these criteria, 7 were rejected outright (including the conventional lead/acid battery) on one or more of these grounds; with zinc-air, zinc-chlorine, sodium-sulphur, and lithium (with chlorine, selenium, tellurium or sulphur) batteries showing some promise, but with doubts and a need for further research and development. However, the battery vehicle seems most suited to short range urban operation, again suggesting the possible evolution of a small specialized urban automobile.

Against the 4 criteria outlined above, flywheels performed fairly well, but suffered from being poor energy storage devices (because of bearing friction) with high self-discharging rates, which might be rectified, however, by further development.

Since these doubts about batteries and flywheels tended to cast doubts on all systems in Groups 1 to 3, Group 4 (on-board energy conversion units) remained to be assessed (see Figure 2.8). These could either be heat engines or fuel cells, and could be used either as a single mode or one of the innovative hybrid power train concepts. Since fuel cells could be rejected on grounds of high cost and limited power output, there only remained the heat engine as a single mode, or in combination with another mode. Of these a hydrogen/electricity system was assessed to be potentially the most promising, although requiring a large amount of development to confirm its potential.

Certain reservations on these assessments (including reservations on the possible evolution of hybrids, and of a small specialized urban car) were expressed by Canadian automobile manufacturers and consultants.

But an overview of the assessments suggests that the evolution of a competitive alternative technology and energy source to the conventional automobile on any scale is not to be relied on in this century, unless oil shortages, prices, or rationing supply strong incentives (see Chapter 3). Such an overview also suggests that (with due reservations) the most promising technological development for the automobile on a substantial scale in this century will be the development and improvement of the conventional internal combustion engine, and the possible development of engines using broader cut or blended fuels (including the diesel), together with the downsizing of automobile size classes which is already taking place.

Materials, Cost and Availability

The combined Canadian and United States automobile industries are one of the largest users of mineral materials in North America. Consequently, the future of the Canadian minerals industry is intertwined with the future of automobile production, design and use.

In addition to meeting the material requirements associated with automobile production, the minerals industry must also adapt to a potential revolution in material use as automobile technologies evolve in response to the need for better gas mileage, environmental controls, increased safety standards and consumer expectations.

In general, world minerals supply is not expected to seriously constrain automobile production within possible ranges of demand, regardless of the combinations of technology, fleet size, weight, or materials mix eventually selected (ref. 14).

However, anticipated changes in both the volumes and variety of materials used in the manufacture of automobiles do raise a number of substantive issues for the Canadian minerals industry. The most important of these possibilities include slower growth in mineral demand (due to down-sizing of automobiles), greater import dependency, problems arising from the substitution of lighter materials for steel, the effects of secondary recovery and recycling on mineral demand, and the integration of the North American auto industry for design purposes which may make it more difficult to orient designs to the Canadian industrial structure. These considerations are considerably wider than the scope of this study, however.

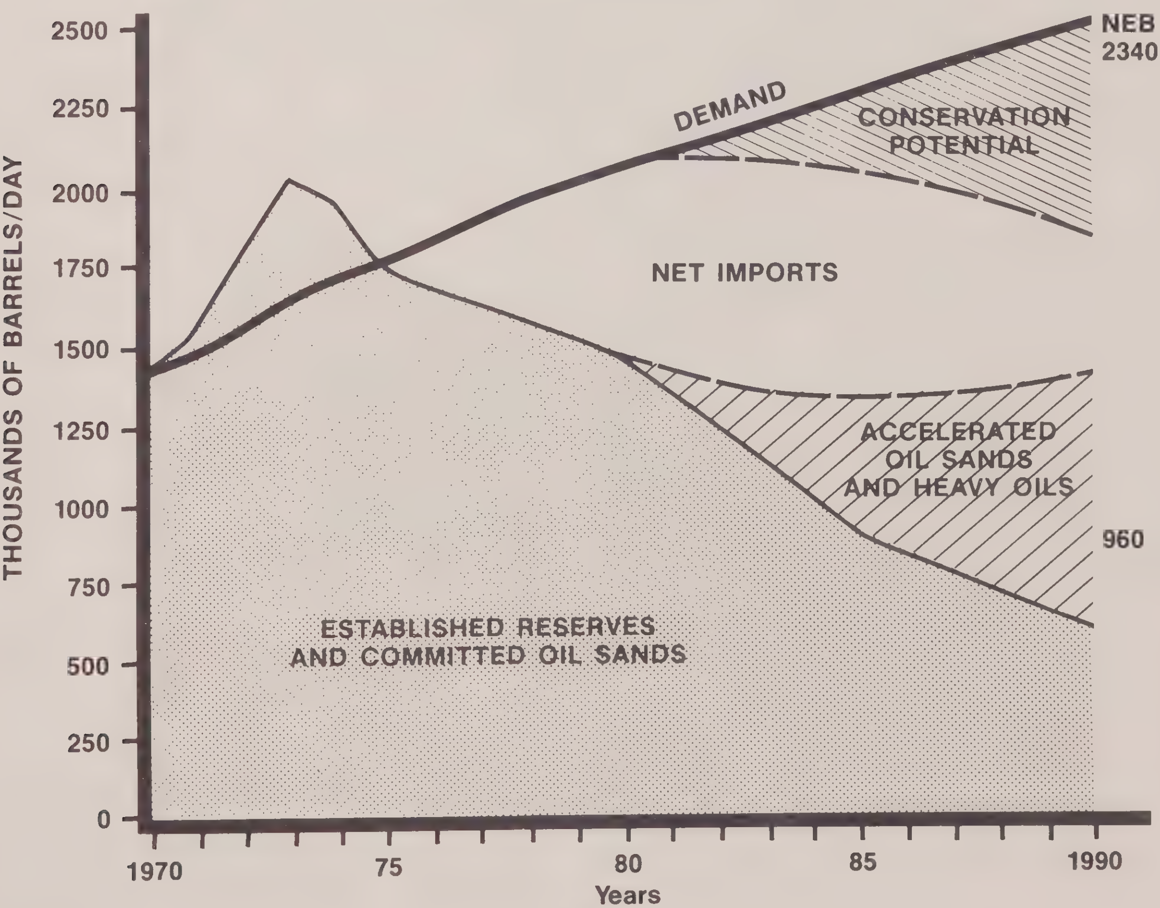
Non-Transport Alternatives to the Automobile — Telecommunications, Computerization and a Shorter Working Week

Telecommunications technology has developed rapidly over the past 25 years for data transmission, audio, and full video communications between the major cities of Canada, and it is therefore necessary to consider their possible impact (by markets) on the use of the automobile and other modes.

Covering the main potential markets (tele-conferencing and home-oriented work centres) in turn, it appears that the most cost-effective means of tele-conferencing will be audio, with a possible market penetration of up to 20% by end-century, mainly taking the place of the air mode, with a possible absolute reduction in air travel of 5-10% by the year 2000 (ref. 15).

Concerning home-oriented work centres (which may be either at the home or at decentralized points), these could have

Figure 2.7 Revised Oil Demand and Availability High Price Scenario 1970-1990



Source: Department of Energy, Mines and Resources, 1977

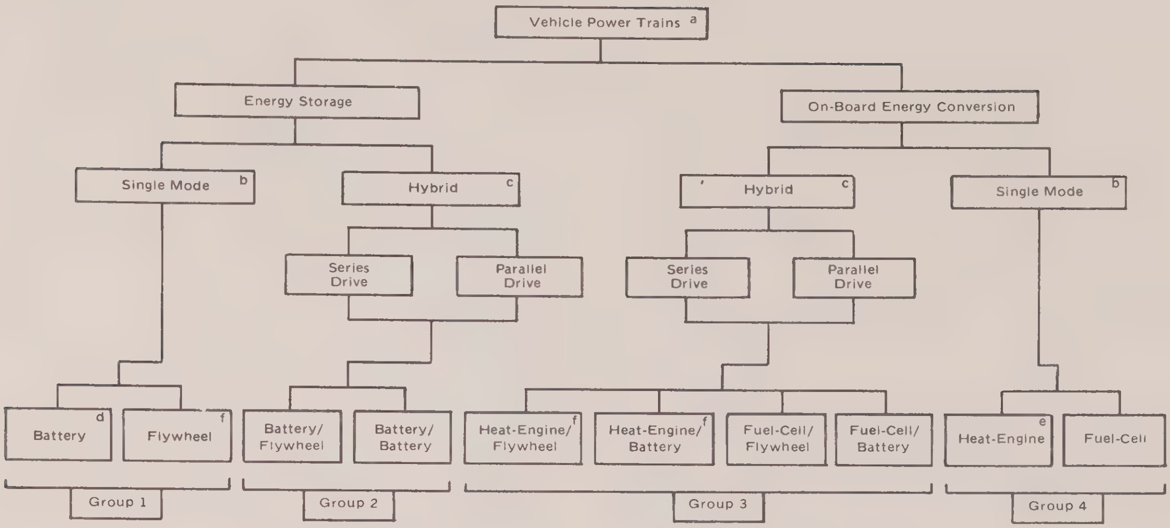
Table 2.1 Example of Changes in Auto Technology and Effects on Fuel Consumption of Median Auto in Normal Growth Situation

	Technology	% Reduction in Fuel Consumption 1975-2000	Cumulative % Reduction in Fuel Consumption 1975-2000
Engines: Conventional	Current trend designs including lean burn and stoichiometric*. Improved induction, control, etc.		
	Advanced current designs employing optimized micro-processor control, some fuel injection, etc.		
Conventional	Advanced Stratified Charge designs, mixture of open and prechamber, injected and valved designs.		
	Advanced Stratified Charge with optimized micro-processor control, fuel injection, etc.	24	
Diesel	Current trend designs.		
	Advanced light weight, high speed units with optimized micro-processor control.		
Engines Using Broad Cut Fuels	Hybrid diesel/stratified charge design; injected, prechamber, spark ignition.		
	Advanced light weight, high speed units with optimized micro-processor control.		
Transmissions:	Advanced conventional designs employing 3/4 speed automatics with lock-ups; 4/5 speed gear boxes.	7	42
	New technology; continuously variable units.		
Vehicle Design: Down-sizing	First generation down-sizing — current trends.		
	Second generation down-sizing.		
Aerodynamic styling	Restyling.		
	Advanced aerodynamic design.		
Material substitution	Aluminum, plastics, etc.	18	
Vehicle Performance (HP/Wt.)	Reduction in large vehicle performance only.		
	First generation fleet performance cut. (About half the second generation level below)		
	Second generation fleet performance cut. Large car 0-60 mph = 15.16 sec., small 0-60 mph = 18.19 sec.		

* Optimal air/fuel ratios.

Source: Flanagan, R.C., "Automotive Technology Assessments and Projections to the Year 2000," Working Paper No. 14, Role of the Automobile Study, Strategic Planning, Transport Canada, 1979.

Figure 2.8 Alternative Automobile Power Trains Assessed



a. Selected as the most promising or most extensively studied power trains. Each of the four groups shown has other power train concepts.

b. Single mode means one energy source for vehicle propulsion.

c. Hybrid means more than one energy source for vehicle propulsion.

d. Most extensively studied, developed, etc. innovative drive.

e. Conventional vehicle drive.

f. Systems that have received major study and/or prototype development.

Source: Flanagan, R.C., "An Examination of the Potential for Innovative Automobile Power Trains", Working Paper No. 15, Role of the Automobile Study, Strategic Planning, Transport Canada, 1979.

a substantial impact on urban travel patterns to work. A home audio work centre (including a computer terminal, and audio, facsimile, and graphic transmission) might soon be available for about $1,000, using ordinary telephone lines to communicate with the employer's office.

However, although these systems would be cheap and possibly popular from the employee's point of view, they pose serious cost, control, and psychological problems from the employer's point of view, and there are doubts whether the home (or remote) work centre can be regarded as a stimulating, efficient, and sufficiently specialized work environment.

Summing up these factors, it seems unlikely that more than about 1% of the work force will substitute telecommunications for existing patterns of travel by end-century, and even then improved telecommunications may tend in fact to stimulate travel, or substitute other trips for the trip to work or business.

With the growth of smaller, cheaper computers, the scope for travel substitution in banking, retail, and generally towards a virtually cashless society seems considerably greater. However, the growth of computerization will either tend to displace labour to other jobs (with no necessary effect on the volume of travel), or result in increased unemployment, with reduced travel, but with serious economic and social problems, and actions to remedy them, which may again restore travel to higher levels. Thus, it appears that in spite of their substantial potentials, the impact of telecommunications and computerization on auto travel by end-century will be small.

Another possibility for substitution for the auto could lie in a change to a 4-day personal working week by end-century, possibly associated with doubling up of jobs over a 5-day period (ref. 16). Potentially, this could reduce total auto use by up to about 7%, but since urban workers would only have to spend 3 nights a week in proximity to their jobs, the effects on "exurban" growth and on recreation travel could more than compensate for the immediate reduction in auto use.

Summing Up

To sum up this technology therefore, it appears that the most likely development of the automobile to attain greater fuel economy will be in the further development of the conventional internal combustion engine, the development of engines using broader cut fuels or fuel blending, e.g., with methanol, downsizing by vehicle class, and by changes in the auto fleet toward smaller classes of automobile.

These are estimated to improve average new car fuel economy from 19 m.p.g. in 1975 to 30.5 m.p.g. in 1985 and to 33 m.p.g. by 2000 in a normal growth situation, with fleet economy improving from 18.5 m.p.g. in 1975 to 24.5 m.p.g. by 1985 and 34.5 m.p.g. by end-century (ref. 17).

In spite of their potentials, it would seem unwise to rely on new auto technologies and energy sources, telecommunications, or computerization to displace the conventional automobile on a large scale during the remainder of this century, unless severe shortages of oil and very high prices (or gasoline rationing) should occur (see Chapter 3).

Chapter 3 — The Future of the Automobile in Terms of Scenarios

The Scenario Approach and Parameters

Decisions, investments, etc., must be made beforehand (not after the event), and it is necessary to plan well ahead for durable and fixed transport systems, urban fabrics, etc., with long time lags for decision making. Also, since serious uncertainties must be dealt with (in the economy, energy and technology), a scenario approach was adopted (ref. 17) and used extensively, though not exclusively, throughout the study.

The object of this scenario approach was not to forecast the future. Rather it was to take certain extreme and central possibilities and parameters in terms of demography, the economy, technology, and energy, etc. (as in Chapter 2), and work out their implications in terms of the automobile, its use, and associated matters. This was done so as to explore the widest possible range of future eventualities and to be aware of their probable consequences if they should occur. Thus, the scenarios tend to be internally consistent packages, each with many results which are explained in greater detail in the working paper on the scenarios (ref. 17). Initially, these scenarios may be described in demographic and economic terms as in Table 3.1 (and illustrated in Figures 3.1 to 3.4), excluding dramatic circumstances such as major wars, etc.

To describe these scenarios in more detail, it may be seen that they first involve 3 basic scenarios; low demographic and economic growth, normal demographic and economic growth, and high demographic and economic growth, with minor energy problems. Demographically, these correspond to annual immigration rates of 60,000, 100,000, and 200,000, and constant fertility rates of 1.8 children per female of childbearing age. Since energy problems will be least in the low and high growth scenarios (see below), to the normal growth scenario can be added two possible energy variations; an energy crisis in about 1985 (with gasoline temporarily rationed at 60% of estimated demand, and with economic recession and slow recovery) and energy conservation, which probably represents the desideratum to be aimed in most respects.

It may be noted from Table 3.1 and Figures 3.1 to 3.4 that the estimated growths in GNP are composed of two factors, the expected growths in households (and the labour force, particularly up to 1985), and growth in GNP per household. For the low growth scenario, GNP per household remains constant over the 25-year period to give a 1.7% annual increase in GNP. For the normal growth scenario, both households and GNP per household rise at 1.95% per annum to give a 3.9% annual increase in GNP, whilst for the high growth scenario both households and GNP per household rise by 2.35% annually, to give a 4.7% annual rate of increase in GNP. For the energy crisis variation, GNP falls by about 14% in the mid-80's (but virtually recovers by end-century), whilst in most things but energy consumption, the energy conserving variation is similar to normal growth (unless otherwise specified) in these and other figures in this chapter.

The Scenario Results

From the basic parameters many general results concerning the automobile, other modes, and general patterns of development can be evolved by using the working papers (ref. 17), and reconciling the estimates into consistent packages, with the variables simultaneously determined in a compatible manner rather than by assumptions. Some of the results are illustrated in Figures 3.5 to 3.8. The sequence of analysis in these figures may be illustrated as follows, although since the equations tend to be solved simultaneously, it is difficult to impose a rigid sequence. However, Figure 3.5 gives the scenario crude oil prices in relation to the Canadian and world oil forecasts given in Chapter 2, assuming that Canada moves to a minimum of the world oil price of $13 per barrel, whilst Figure 3.6 gives the corresponding gasoline prices (inclusive of taxation) appropriate to each scenario. Crude and gasoline price increases (to $35 per barrel and $2 per gallon) will be most severe for the energy crisis and energy conserving variations, but at a medium level ($25 and $1.50) for the normal growth and low growth scenarios, and least (at $13 and $1.25) for the high growth scenario which assumes minimal oil supply problems.

In response to demographic and economic growth and the energy situation, auto mileage travelled (AMT) tends to increase as in Figures 3.7 and 3.8, the increases varying from 87 billion in 1975 to 113 billion by the year 2000 for the low growth scenario, to 210 billion AMT for high growth, with an intermediate level (172 billion) for the normal scenario. It may be noted that the oil crisis variation would involve a 40% drop in AMT arising from rationing to meet 60% of demand, but with a fairly substantial recovery and growth in AMT after that date. Most of the increases in AMT will be generated by the 22 CMA's as shown in Figure 3.8.

These forecast growths in AMT, together with the new car price trends given in Figure 3.9 (in which down-sizing tends to almost compensate for increasing auto costs) give the auto fleet sizes as in Figure 3.10. These increases (from the 9 million level in 1975) are expected to range to about 11 million units in the year 2000 for the low growth scenario (at the 1975 level of 0.39 cars per head) to about 17 million units in the year 2000 for the high growth scenario (0.52 cars per head), with about 14 million fleet size by end-century for the normal growth scenario (0.47 per head). The fleet sizes estimated in Figure 3.10 will result in the new car sales given in Figure 3.11 to cover fleet growth and scrappage. For the low growth scenario, annual new car sales are likely to stabilize at the 1975 level of about 1 million units per annum, for the high growth scenario they are likely to increase to about 1,700,000 units by end-century, and to 1,300,000 to 1,400,000 units by end-century for the normal scenario, but with a brief drop in new car sales to about 750,000 units per annum for the oil crisis variation.

The new car fuel economies corresponding to the growth and replacement of the automobile fleet are given in Figure 3.12 with new car economy improving from about 19 m.p.g. in 1975, to about 35 m.p.g. for the low growth, 34 for the normal growth, and 33 m.p.g. for the high growth scenario by end-century, and to 43 to 46 m.p.g. for the oil crisis and energy conserving variations. Both variations provide strong incentives to fuel economy in response to gasoline prices at $2.00 per gallon (1975$) in the year 2000. Actual fleet economy will improve from about 18.5 m.p.g. in 1975 to 30-32 m.p.g. by end-century for the 3 scenarios, and to 38 m.p.g. for the variations.

All these estimates culminate in the figures for total auto fleet consumption given in Figure 3.13 and the proportions of oil imported in Figure 3.14. Except for the high growth scenario, total oil consumption is expected to stabilize (normal growth) or fall (for low growth, and the energy crisis and energy-conserving variations) with oil imports peaking at about 40% of total consumption in the mid-eighties, but declining to 0-15% of total consumption by the year 2000 with declining balance of payment deficits on auto oil account.

A useful by-product of this analysis, i.e., the compatible macro forecasts for the usage of other modes, can be derived from the scenarios and appropriate working papers (refs. 18 and 19), and are given in Figures 3.15 to 3.18. Domestic air travel is (and is expected to be) the largest and most expansionary mode with increases by end-century ranging

from modest for the low growth scenario, to almost a fivefold increase for the high growth scenario, with about twofold increases to be expected for the normal growth scenario, and the energy conserving and oil crisis variations. The rates of increase to be expected for the other modes are much more modest, with light increases for the rail and bus modes, and an approximate doubling in expected transit usage by end-century for all scenarios. For the oil crisis variation, bus, rail and transit usage would jump significantly and carry on increasing substantially, whilst air travel would temporarily fall.

One point that must be stressed in these scenarios is the connection between growth, energy and technology, in that higher growth and greater energy problems will lead to greater technological development and greater energy research and the development of new energy sources. Lower growth and less important energy problems will result in less technological and energy development, whilst creating problems of their own in terms of stagnation, higher unemployment, etc.

These results of the various scenarios inevitably concentrate on broad results at the national level, and must be supplemented by more detailed analysis at the urban, inter-city, and rural levels in subsequent chapters.

Table 3.1 Descriptions of Scenarios in Terms of Demographic and Economic Variables

Scenario*	Variation	Population millions		Household millions		GNP $ billions		Average Annual Rate of Increase in GNP %
		(1975 = 22.8)		(1975 = 6.8)		(1975 = 161)		
		1985	2000	1985	2000	1985	2000	1975-2000
Low Growth		25.1	28.2	8.7	10.5	205	248	1.7
Normal Growth	Energy Crisis (1985)	25.7	29.6	9.0	11.1	243 209**	381	3.5
Normal Growth		25.7	29.6	9.0	11.1	243	381	3.5
Normal Growth	Energy Conserving	25.7	29.6	9.0	11.1	243	417	3.9
High Growth (no energy supply problems)		27.2	33.1	9.5	12.3	265	518	4.7

* In the working papers, these scenarios are termed: 1) PARALYSIS, 2) NO SURPRISES, and 5) CALIFORNIA respectively, with the Energy Crisis as Scenario 3) 1985 THE TURNING POINT and Energy Conserving as Scenario 4) THE ENERGY CONSERVING SOCIETY (ref. 17).

** Fall in GNP.

Figures 3.1-3.4 Demographic and Economic Variables

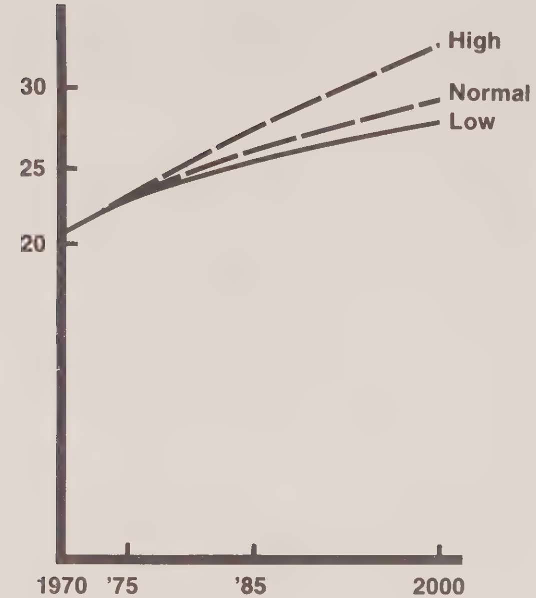


Figure 3.1 Population (millions)

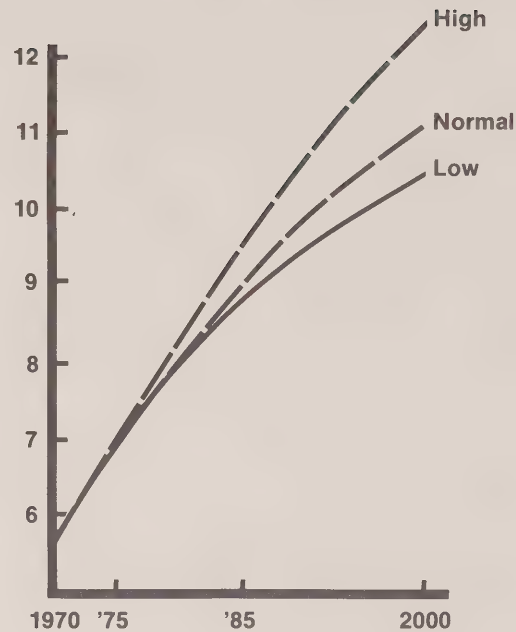


Figure 3.2 Households (millions)

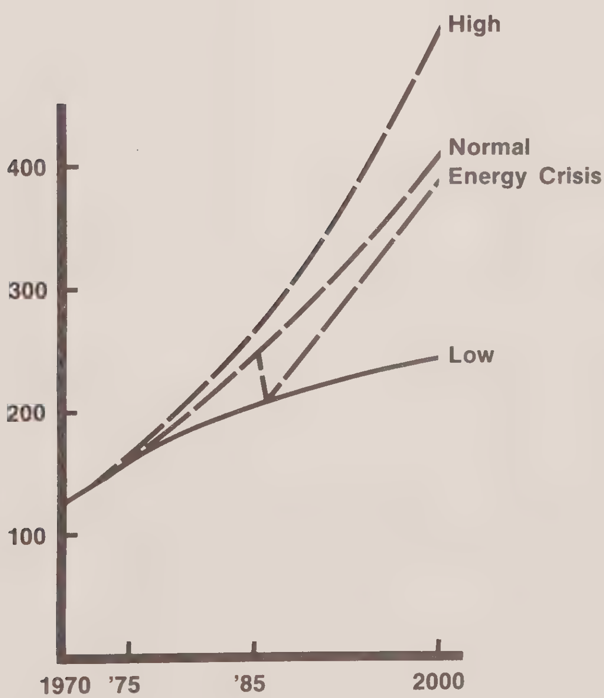


Figure 3.3 GNP ($ billions)

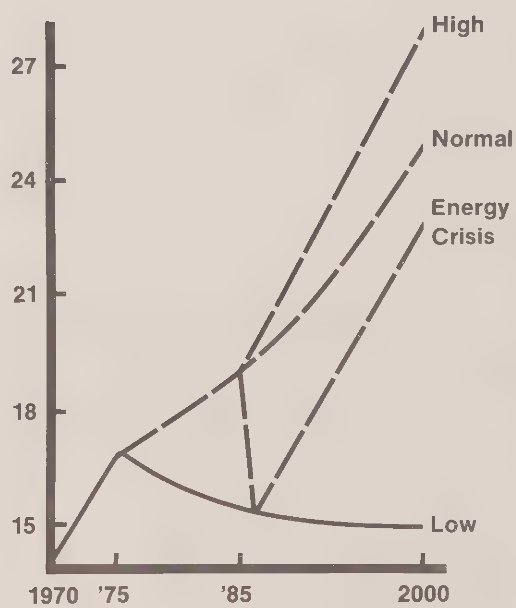


Figure 3.4 Average GNP per Household ($000)

Source: Frayne, A., "Scenarios for the Role of the Automobile", Working Paper No. 18, Role of the Automobile Study, Strategic Planning, Transport Canada, 1979.

Figures 3.5 and 3.6 Energy Variables

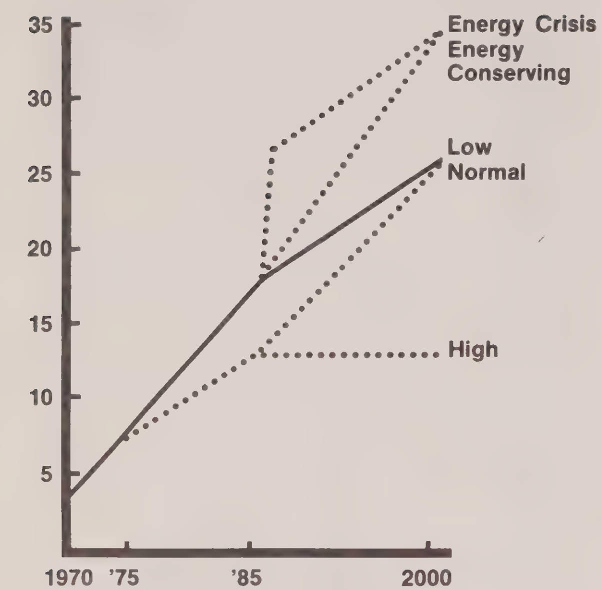


Figure 3.5 Crude Oil Price ($ per barrel)

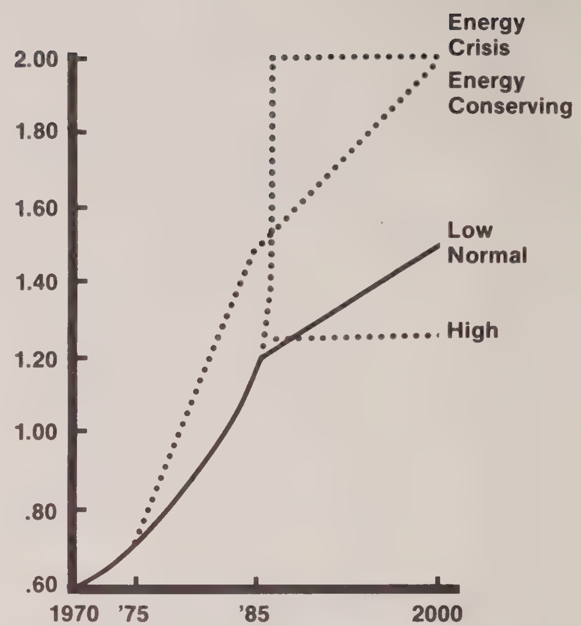


Figure 3.6 Gasoline Price ($ per gallon)

Source: Working Paper No. 18.

Figures 3.7 and 3.8 Annual Automobile Mileage (AMT) (billions)

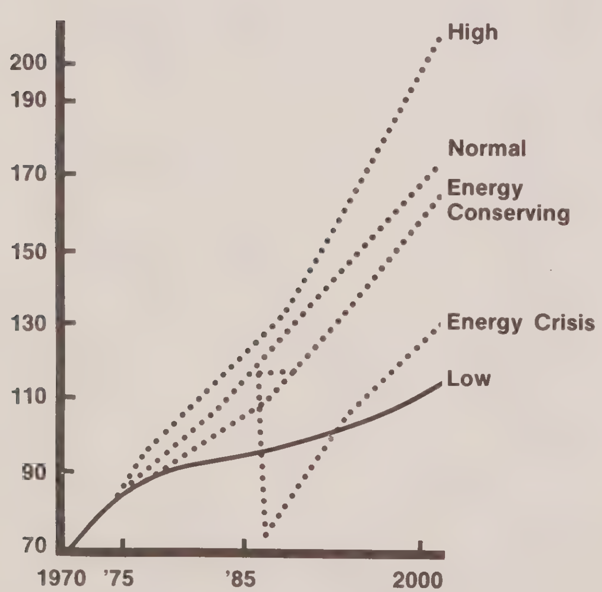


Figure 3.7 Auto Miles Travelled (AMT)

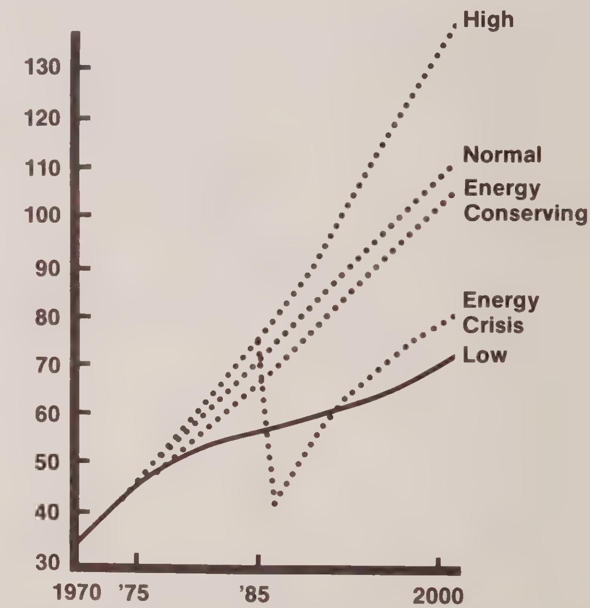


Figure 3.8 AMT by CMA Residents

Source: Working Paper No. 18.

Figures 3.9-3.12 Automobile Fleet Characteristics

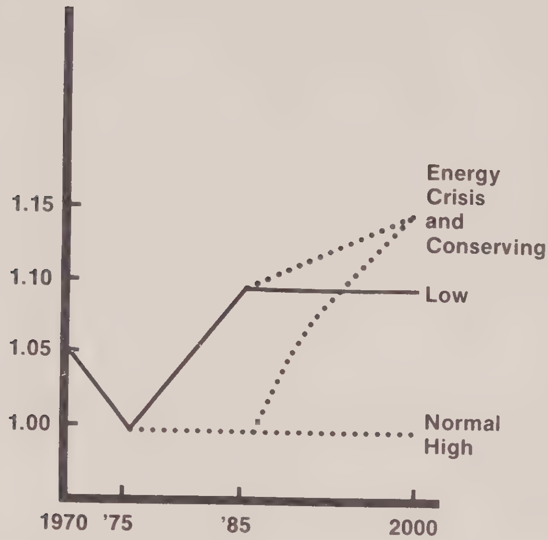


Figure 3.9 New Car Price Index (1975 = 1.00)

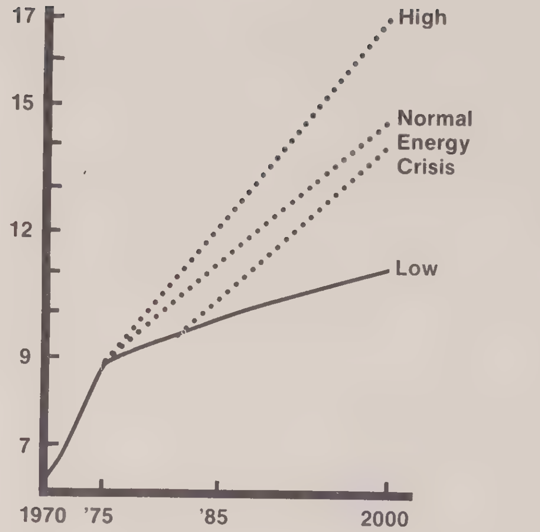


Figure 3.10 Automobile Fleet Size (million units)

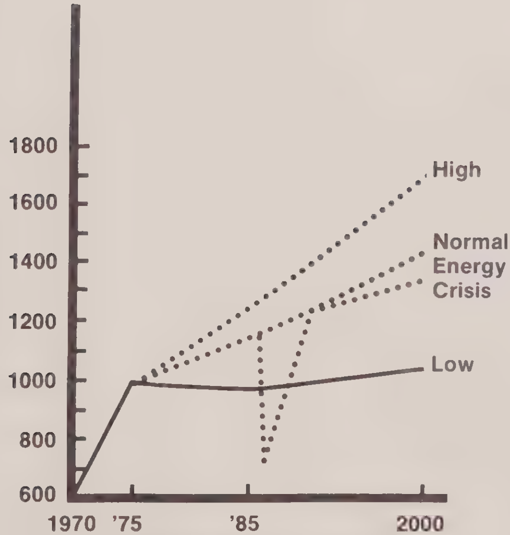


Figure 3.11 New Car Sales (thousand units)

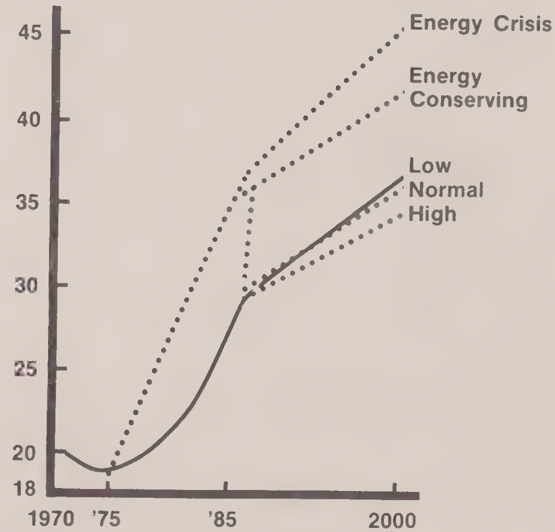


Figure 3.12 New Car Fuel Economy (m.p.g.)

Source: Working Paper No. 18.

Figures. 3.13 and 3.14 Total Auto Gasoline Consumption and Oil Imports

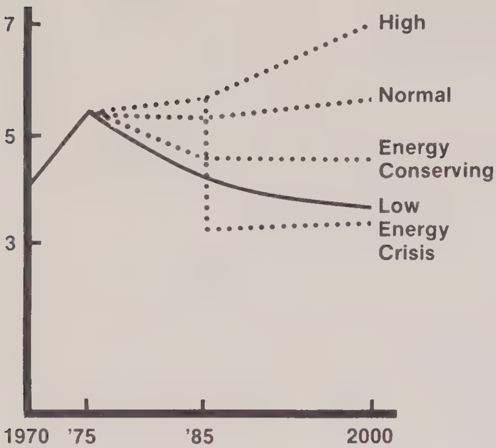


Figure 3.13 Automobile Gasoline Consumption (billion gallons)

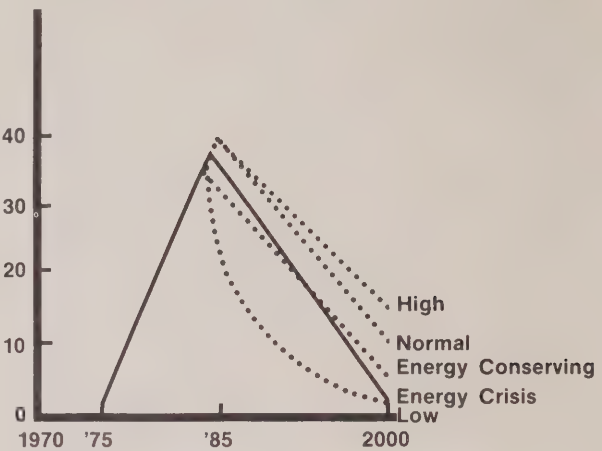


Figure 3.14 Proportion of Oil Consumption Imported (%)

Source: Working Paper No. 18.

Figures 3.15-3.18 Usage of Other Modes (in billions of passenger miles per annum)

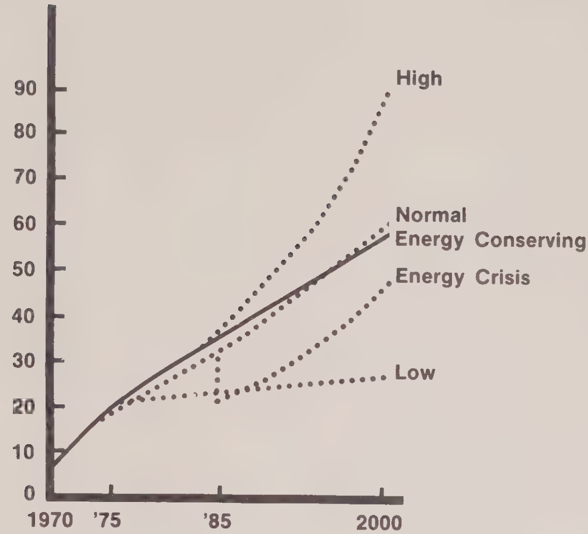


Figure 3.15 Air Travel

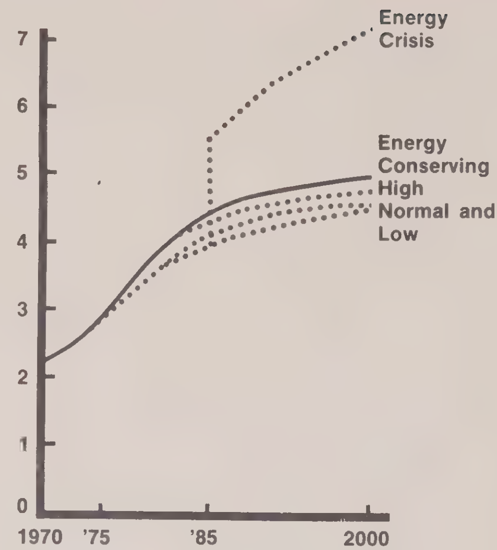


Figure 3.16 Bus Travel

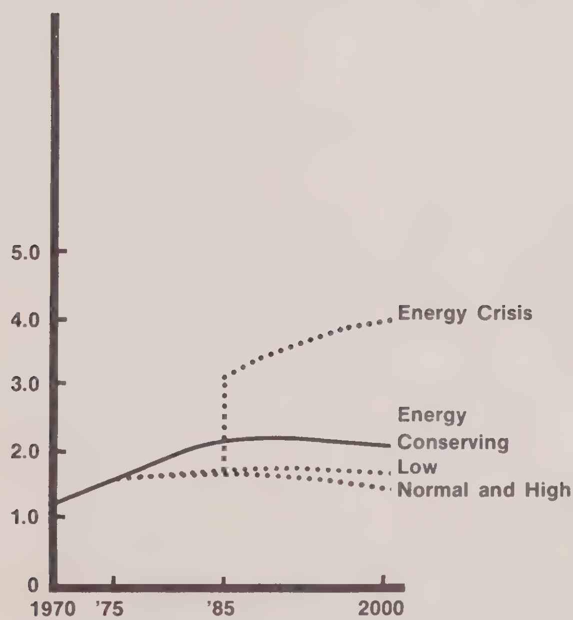


Figure 3.17 Rail Travel

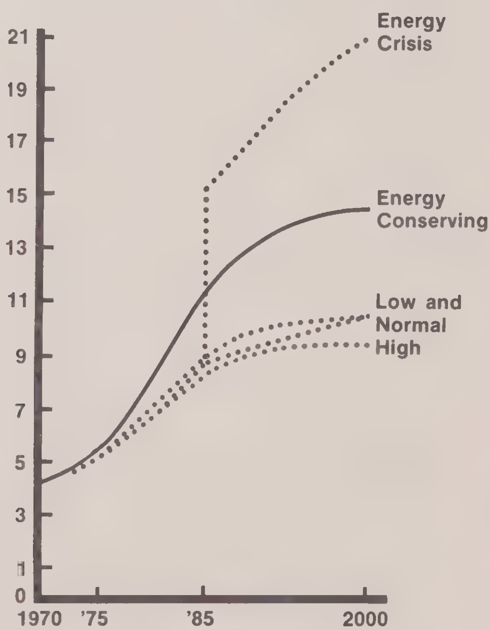


Figure 3.18 Transit Usage

Source: Working Paper No. 18.

Chapter 4 — The Automobile and Transit in an Urban Context

In addition to the macro-forecasts for urban areas in the scenarios given above, the potential scope for interaction and change for the automobile in an urban context (with its private benefit, public nuisance aspects) is so great that it is necessary to analyze the matter in more detail.

Such an analysis may be divided into two parts, a basic analysis of transport, the auto, and transit for typical situations in a typical Canadian city in 1975, and a more dynamic analysis concerned with the growth of Canadian cities up to end-century, and the consequences of this growth for auto use, transit and other urban variables such as trip lengths, speeds and gasoline consumption.

Basic Considerations Concerning the Costs of Urban Travel by Mode 1975

For this basic study (ref. 20), the concept of cost was used, including the full social costs of trips, to discover the most cost-effective (or least cost) mode for the various types of person-trip, for example, core-oriented and non-core oriented trips. Social costs were defined to include the costs of congestion (imposed on others), energy depletion and accidents, expenditures from the public purse on roads and transit subsidies, and the market prices of parking. In addition, all costs were expressed on a comparable replacement cost basis, taking account of the expenditures required (on this basis) to provide additional capacity for moving traffic, including the value of passengers' time (at $3.00 per hour per example) where appropriate.

The results of this analysis for the automobile and transit, for core-oriented trips (illustrated in Figure 4.1) and non-core-oriented trips may be summarized as follows.

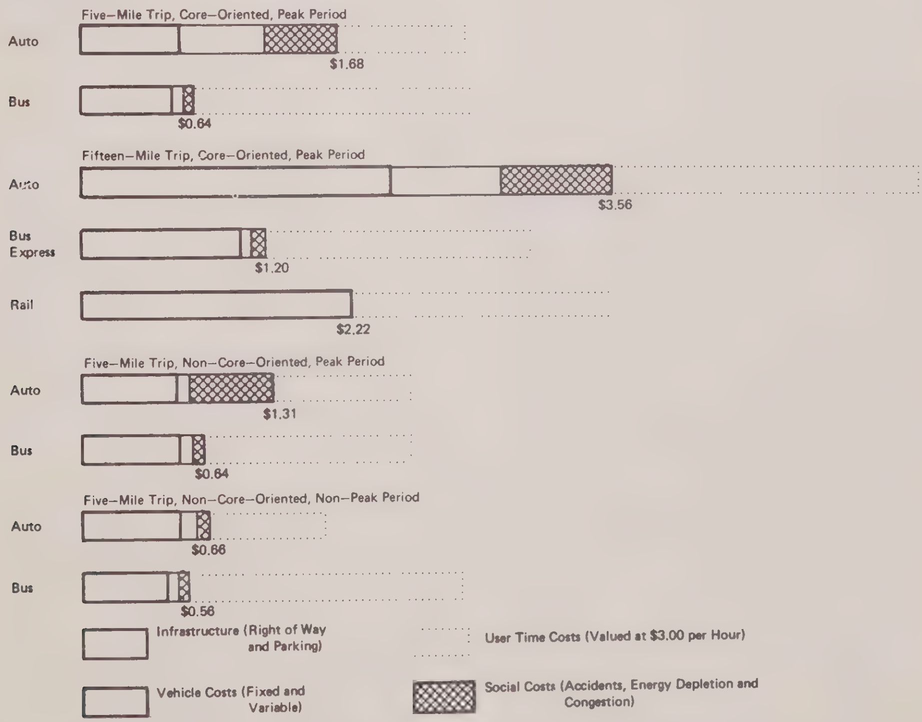
Core-Oriented Trips

Trips into or out of the urban core only account for a minor share of all urban travel, estimated at less than 20% in most cities. However, such trips are a particularly important segment of urban transportation, as they are those which account for the greatest social costs of automobile use, and those which are more amenable to service by transit.

As shown in Figure 4.1, core-oriented trips by automobile during peak periods are estimated to cost $1.68 per passenger for a five-mile trip if the individual's cost of time is excluded. The major elements of this cost are the individual's out-of-pocket expenses (41%), parking costs based on present commercial rates (29%), and the social cost of congestion (21%), arising from the time loss imposed on other travellers by additional vehicles on congested routes. Total cost varies considerably if the number of occupants changes or if congestion becomes more severe — an overall 30% drop in average speed due to higher congestion would raise automobile costs by 30%. However, total costs are affected relatively little by changes in fuel prices or the use of sub-compact cars (ref. 20).

Bus costs are substantially lower than automobile costs on

Figure 4.1 Total Costs of Urban Passenger Trips



Source: Frayne, A., and F. Kagan, Urban Transportation Research Branch, Transport Canada, "The Costs of Urban Travel in Canada", Working Paper No. 28, Role of the Automobile Study, Strategic Planning, Transport Canada, 1978.

core-oriented trips. On a five-mile trip they average $0.64 per passenger if the individual's cost of time are excluded. This cost is very sensitive to the number of occupants and to the average speed, as the major elements of cost (such as labour) are dependent on time. They are almost unaffected by plausible increases in fuel costs and do not change drastically with changes in trip distance.

On longer bus journeys, major economies can be achieved through the use of express lanes, bus priorities over other traffic, etc., so that costs become similar to those on inter-city bus service with its much lower average cost per mile. At $1.20 per passenger for a 15-mile trip, the bus is cheaper than the rail mode for such trips, data obtained on the GO Lakeshore service indicating a trip cost of $2.22 for a fifteen-mile trip.

Non-Core-Oriented Trips

The automobile is far more competitive with transit on the non-core-oriented trips that constitute the greater part of urban travel. Auto costs are estimated at $0.96-$1.31 per five-mile passenger trip, depending on whether or not significant congestion is encountered on the route. The average cost of non-core-oriented bus service is not noticeably different from core-oriented service. Costs are $0.64 per passenger trip on congested routes and $0.56 on uncongested routes. However, it should be noted that, as occupancies on such transit services are usually very low compared to the vehicle capacity, the marginal cost of an extra passenger is often almost zero. Smaller buses appear to have little effect in reducing average costs.

Travel Time and Trip Costs

None of the above cost estimates includes an allowance for the individual's cost of time. This is a personal cost, to be distinguished from the social cost of congestion imposed by one traveller on all other travellers. A value of time of $3.00 per hour is used to estimate total costs including the individual's cost of time; the same value is used in computing the cost of congestion.

When the individual's time loss is considered, non-core-oriented trips are cheaper by the automobile than by bus, as bus journey times are typically twice as long as those by auto. Even for core-oriented trips, costs by bus rise almost to equal those by auto, unless measures are adopted to accelerate bus service above the typical present speed of 10 m.p.h. If express bus or rail is used and door-to-door journey times become as short as by car, then transit can show a substantially lower cost than the automobile. This is illustrated by the costs of a 15-mile trip shown in Figure 4.1. These estimates are very sensitive to the value of time used, however.

However, there is a social benefit not included in the above figures which accrues from transit use when users' time is valued. If transit ridership increases, the level of service should improve. This may be through the use of more vehicles so that frequency increases and routes expand. At certain levels it may be through a change in the system, e.g., the use of exclusive rights of way or rail transit. In general, these improvements will act to reduce the time of any journey by transit. It is in this sense that there are economies of scale to transit use, and this may be considered one of the major arguments for subsidization of transit (see Chapter 1 and below in this chapter), amongst others such as reduction in congestion, etc.

Time thus plays a crucial role in assessing the costs of urban travel in terms of social costs (congestion), social benefits, transit operating cost (labour cost), and the individual's cost. If no allowance is made for the latter, bus travel compares well with auto travel. But if the value of users' time is considered, the auto has a lower total cost on all non-core-oriented trips, and the bus can only show a clear advantage if services are accelerated from their current speeds.

Implications of the Basic Analysis

This analysis of the basic costs of urban travel resulted in the following general conclusions.

1. Urban travel costs are high but most users' decisions do not take into account all of the relevant costs.
2. The most significant social cost of urban automobile travel is central congestion, estimated at 10 cents per automobile mile. Spreading traffic peaks through staggering hours of work, schools, shops, etc., could reduce this cost significantly as would pricing systems for core-oriented auto trips, if practical and acceptable systems could be evolved.
3. From a total cost viewpoint, it is preferable that trips into the urban core in peak periods be taken by transit, which has substantial economies of scale which can justify its subsidization.
4. The costs of core-oriented car trips should be augmented to reflect a higher proportion of total costs to society.
5. For non-core-oriented trips, transit is less efficient than the car. This relative inefficiency is probably increasing over time.
6. Increases in gasoline prices have relatively little effect in increasing total urban travel costs.
7. The most effective strategy for lowering the total costs of transit usage is to lower trip times via higher speeds, express buses, etc.
8. Rail service is a high cost option only justifiable in isolated cases.
9. There is circumstantial evidence (though obscured by the factors mentioned above) that since there is no price for auto use (but a variety of expenditures largely disconnected from use), auto users do not fully perceive even their own costs of auto use. This point seems best returned to and illustrated in the simpler inter-city context of Chapter 5.

The Expanding City — The Automobile and Transit in Relation to Urban Growth, Housing, Job Distribution and Gasoline Consumption 1975-2000

Turning to more dynamic and future-oriented analysis, it is becoming increasingly clear that, although the use and dependence on the automobile is considerably greater in rural and smaller urban areas (see Chapter 1, Table 1.2), the major impact, increase, inter-action and scope for change in the role of the automobile is in the larger urban areas, which are growing most rapidly (see Chapter 3). However, the inter-action of the automobile and other transport modes with urban development and growth does pose some formidable problems. First of all, it seems that we are mainly concerned with the spatial relationship and integration between four subjects which are normally handled semi-independently, each with their own pressures, priorities and problems. These are urban housing, the growth and location of jobs, etc., (on which data and knowledge are scarce), urban planning, and personal transportation. Personal transportation, therefore, between housing, jobs and other attractors, plays a rather subsidiary connecting role in this context, despite the dominance of the automobile in urban areas.

Secondly, since household formation and housing seem to be the front runners of urban growth in Canada (or second to jobs), since almost all automobile trips are home-based, and since housing is more dispersed than jobs, etc. (see below), the location of housing seems to have a dominant effect on urban automobile use. It is necessary, therefore, to achieve a close integration between housing and internal urban transport. Since this does not seem to have been attempted before in a factual context, the analysis was, to a considerable extent, a pioneering exercise (ref. 7) aided by analysis of travel to work data derived by Statistics Canada from the 1971 census and subsequent studies.

Table 4.1 Estimated Average Straight Line Distances of Dwellings from CMA Centres and Actual and Estimated Auto Trip Lengths to Work 1975

CMA	Estimated No. of Households 000's	Estimated Population 000's	Estimated Average Straight line Distance of Dwellings from CMA Centre — miles	Actual (a) & Estimated (b) Average Auto Trip Length to Work — miles 1975
Toronto	925	2,750	5.8	10.9 (a)
Montreal	925	2,800	4.9	9.9 (a)
Vancouver	412	1,150	5.5	9.8 (a)
Ottawa-Hull	222	640	3.7	8.1 (a)
Winnipeg	198	580	2.9	7.0 (a)
Edmonton	178	560	3.3	7.8 (a)
Hamilton	175	530	3.7	10.2 (a)
Quebec	150	510	3.0	6.6 (a)
Calgary	150	480	2.9	7.0 (a)
St. Catherines	111	310	3.4	7.6 (b)
London	104	300	3.4	7.6 (b)
Windsor	86	270	3.0	7.1 (b)
Kitchener	84	240	2.7	6.6 (b)
Victoria	81	210	2.5	6.4 (b)
Halifax	76	220	2.6	5.7 (a)
Regina	48	150	2.0	5.7 (b)
Sudbury	46	160	4.4	9.0 (b)
Saskatoon	43	130	1.8	5.4 (b)
Chicoutimi	41	140	2.2	6.0 (b)
St. John's	36	130	3.1	7.1 (b)
Thunder Bay	35	110	2.2	6.0 (b)
St. John	34	120	4.0	8.5 (b)
	4,160	12,500	4.4 (c)	8.9 (c)

Notes: (a) Actual Average Trip Length to Work
(b) Estimated Average Trip Length to Work using Equation 1 (Appendix 4A)
(c) Weighted Average in terms of households

Source: Working Paper No. 9.

Urban Size and Housing, Auto Trip Lengths to Work and Other Urban Trips

As explained above, since almost all auto trips are home-based (or destined) and household and housing growth seem to be the main leaders in Canadian urban growth, it is important that urban auto trip lengths and auto use be correlated with urban households and housing. Further, there has been recent evidence from the 1971 census travel to work for Ottawa-Hull, from international comparisons between cities, and from Sweden (ref. 7), that the average distance of housing from city centres (although few may work there), is the major determinant of average trip length to work which account for the major part of urban auto use (see Table 1.2). There seems to be little apparent effect on work trip lengths from the distribution of work places, dispersal of work places merely tending to make trips more dispersed and auto-oriented, centralization of jobs making work trips more central and transit-oriented (ref. 7). The detailed evidence and work connecting housing location with trip lengths to work is given in Appendix 4A.

Applying Appendix 4A to the estimated average distances of dwellings from the centres of the 12 smaller CMA's, it is possible to estimate auto trip lengths to work for all 22 CMA's as in Table 4.1.

Concerning Table 4.1, it must be noted that the lack of geographical detail in the smaller CMA's makes it more difficult to estimate the mean distance of CMA dwellings from CMA centres (and thus auto trip lengths) accurately. But the detail in, and influence of Toronto, Montreal, and Vancouver on weighted average trip lengths are so great (accounting for about 62% of total CMA auto travel to work — see Table 4.4 below) that this is of little national importance.

More importantly, the weighted average trip length at 8.9 miles agrees with the (1976) results of the national automobile survey (ref. 6) on the assumption that the average CMA household carries out 480 auto work trips a year (for example, 2 daily work trips per household for 240 days) to drive 18 billion auto miles to work for the 22 CMA's in 1975 (see Table 4.5 below).

To complete the reconciliation between urban and total auto vehicle mileage on a national scale, it is useful to consider the broad results of the 1976 national automobile survey presented in Table 1.2.

Allocating all auto mileage originating in urban areas, devoted to external business, week-end recreation and vacation, to rural and inter-city auto mileage, the resulting division of auto mileage between urban and rural areas becomes as shown in Table 4.2.

The allocation of auto mileage given in Table 4.2 results in an urban/rural split of 59/41, which agrees fairly closely with the generally assumed national division of 55% urban and 45% rural. Table 4.2 also shows that urban commuting (with a close connection with housing) accounts for about 43% of internal urban automobile use and that other home-based internal urban auto trips (principally daily recreation, personal business and shopping) account for about another 25%. Thus,

about two-thirds of all internal automobile travel seems fairly directly connected with the location of housing. This suggests that there is probably a close connection between urban size, housing location and all internal urban auto mileage. However, for urban based auto mileage outside urban areas, there seems to be little connection between urban size, etc., and auto use, except for a tendency towards larger auto mileages and longer trip lengths for week-end recreation and vacation with increased urban size (ref. 6). Urban-rural (ref. 6) type trips are probably a function of income (elasticity 1.0 approx.) and the geography of attractive points, and inter-city trips (income elasticity 0.8 approx., ref. 6) a function of city populations and distances between them (see Chapter 5).

It may hopefully be seen from this section that, although the individual components and relationships may be weak and tentative, by reconciliation with independent estimates and thus closing the structure, it is possible to produce a fairly strong framework for estimating the current urban role of the automobile and placing it in a causal context.

Table 4.2 Estimated Allocation of Auto Mileage Between Urban and Rural Areas 1975

Area of Origin	Internal Urban Auto Mileage (billions)	Other Auto Mileage (Rural and Inter-City) (billions)	Total
22 CMA's	35	12	47
Urban areas 25,000-100,000 Population	6	2	8
Urban areas 1,000-25,000 population	9	3	12
Rural areas	1	19	20
Total	51*	36**	87

* Of which urban commuting accounts for about 22 billion auto miles or 43%.

** Of which rural probably accounts for up to 28 billion, inter-city at least 8 billion.

Source: Working Paper No. 9.

The Current Role and Function of Urban Transit

There are difficulties in estimating the role and function of Canadian urban transit because data is normally recorded in terms of passenger trips, rather than passenger mileage. However, two independent estimates, by IBI Group (ref. 24) and Canada Resourcecon, estimate total urban transit passenger mileage in 1975 at about 5.25 billion. With some 1.16 billion revenue passenger trips in 1975 (97% in the CMA's), this implies an average transit trip length of about 4.5 miles. Further, assuming an average urban auto occupancy of 1.4 (ref. 20), the estimates in Table 4.2 imply that transit accounts for about 10% of total internal CMA passenger mileage. Other non-motorized transport modes (walking, cycling, etc.) account for substantial proportions (perhaps 10%) of internal urban trips but their trip lengths are so short (almost all less than 1 mile), (ref. 7), that they only account for about 1% of urban passenger mileage and can be ignored for general purposes. Of the total CMA transit trips in 1975, it appears that travel to work accounted for almost half (or 600 million), (ref. 7). However, with the long average transit work trip length (up to 7.7 miles at an average speed of 13-14 m.p.h.), work trips seemed to account for almost 75% (4 billion) of CMA transit *passenger* mileage.

It seems clear, therefore, that the major market and function of urban transit is in the trip to work in the major urban areas. This is supported by the data in Table 4.3 from the Statistics Canada Travel to Work Survey in 1975 (ref. 7).

It may be noted from Table 4.3 that such is the weight of Toronto and Montreal in transit work trips that the average overall usage of transit for work trips in all CMA's is fairly high at 26%, although it probably falls below the 20% level in the 13 smaller CMA's with 1975 populations below 500,000.

It may also be noted that transit use is not very sensitive to CMA population size, and that although "availability" of transit is not defined, it does not seem to have a very significant effect on transit use. Clearly, other factors are important in determining the usage of transit.

Some of these other factors affecting the use of transit seem to be travel distance and travel time *per se*. The Statistics Canada survey (ref. 7) shows that transit use rises from 15% for trips of less than one mile, to 29% for trips of 1-2 miles, to a peak of 33% for trips from 3-10 miles, falling thereafter to 25% for trips from 11-20 miles and to 17% for trips of more than 20 miles, probably because of lack of available, suitable services. Other things being equal, therefore, further modest urban growth may improve the propensity to use transit, provided that additional jobs are in the CBD and services can be extended economically in terms of costeffectiveness and energy (see below).

Concerning total travel time (including walking and waiting), the survey shows, for example, that a doubling in speed for the same trip length would increase transit usage by 22% (ref. 7). Finally, the Statistics Canada survey (ref. 7) outlines quasi-social variables which appear to affect transit use positively (female sex, unmarried status, short working hours and service occupations) and negatively (age and managerial status). On balance, the combined effect of these variables may be favourable to transit use, mainly due to the anticipated continuation of growth in the female component of the labour force. However, there is recent, but as yet inconclusive, evidence that this may be offset and actually reversed by the growing financial independence, car ownership and use by women.

Table 4.3 Work Trip Transit Usage in the Nine Largest CMA's 1975

CMA	1975 Population 000's	% of Trips to Work Made by Transit 1975	% of commuters to which transit "available"
Toronto	2,750	35	82
Montreal	2,800	32	81
Vancouver	1,150	20	73
Ottawa-Hull	640	31	74
Winnipeg	580	27	85
Edmonton	560	22	64
Hamilton	530	20	70
Quebec	510	16	66
Calgary	480	20	80
All CMA's	12,500	26	77.5

Source: Statistics Canada Travel to Work Survey 1975 and Working Paper No. 9.

There seems to be little data (ref. 7) to connect transit use directly with density, type of dwelling and the degree of centre-orientation of jobs, although it is well known that these variables can be influential, particularly the latter. But a study (ref. 7) of urban densities and public transportation concludes that:

> "Residential density is less important for transit use than proximity to a downtown of substantial size or proximity to a rail transit line. If greater transit use is the goal, it is more important to put housing close to a downtown than to make it high density."

The important point seems to be that in order to make transit use attractive for work, conditions must be satisfied at both trip ends and en route, for example, high residential density, centre-oriented jobs and heavy passenger volumes. The satisfaction of only one condition may be ineffective, although there seems little doubt that the construction of the Toronto subway, together with rapid household formation in the younger age groups, led to the construction and concentration of high density development on the subway in the 1950's and 1960's (ref. 8).

To conclude this brief survey of the 1975 status of urban transit, it must be pointed out that although the absolute number of transit trips has been rising from 1971-75, the propensity to use transit (when available) for work trips has declined from 32% to 30% of total trips in the period 1973-75 (ref. 7), although quasi-social factors and urban growth may tend to be slightly favourable to the future use of transit.

Unconstrained Auto Usage as a Function of Household and Housing Growth

Having explained and reconciled 1975 auto use with CMA size and average dwelling distances from centres, it is a difficult task to estimate the unconstrained change in auto use with the expected household growth of individual CMA's in the future, and this task is therefore relegated to Appendix 4B.

To estimate the growth of auto mileage to work as a function of household and dwelling growth by the application of Appendix 4B in detail is an erratic task for many reasons. First of all, because of the wide range of sizes in CMA's and their expected differential rates of growth, it is necessary (for accuracy's sake), to estimate auto mileage separately for each CMA at some stage in the analysis rather than making a broad estimate for the whole. However, this raises considerable problems of accuracy for the individual CMA's because CMA household forecasts are usually made by demographic means, and it is more difficult to forecast the necessary and complementary job growths with the same degree of accuracy for individual CMA's. Thus, the individual forecasts of households and auto mileages have little significance *per se*, their main functions being to ensure a reasonable accuracy in the total forecasts and to act as an indicator of important trends and orders of magnitude.

Although the forecasts for the 22 individual CMA's (for normal growth) as shown in Table 4.4 have little individual significance, some important factors and trends may be noted. First of all, Toronto, Montreal and Vancouver account for 62% of total CMA auto travel to work (and perhaps of total internal CMA auto mileage) because of size, and, in spite of the expected slower growth of Montreal, they are still likely to account for 64% by end-century. Secondly, it may be seen that, very broadly speaking (with the exception of Montreal), the larger the CMA the greater its expected rate of growth in households, trip lengths, and internal auto mileage. Thus, only 5 CMA's, Toronto, Vancouver, Ottawa-Hull, Edmonton and Calgary may have above average rates of growth in these variables, and the remaining 17 CMA's can be expected to experience below average rates of growth in these magnitudes.

Finally, it may be noted that unconstrained CMA auto use to work can be expected to increase (in the normal growth scenario) to about 1.67 times the 1975 level by 1985, and to 2.33 times the 1975 level by end-century, with the absolute increases in auto mileage being almost identical in the 1975-85 period and the 1985-2000 period.

The estimates for the low growth and high growth scenarios are presented in Table 4.5 in terms of the physical growth approach. To summarize, low growth in physical terms would generate a 53% increase in internal CMA unconstrained auto mileage by 1985, and a 115% increase by 2000, somewhat higher and more concrete increases than the scenario macro forecasts (Chapter 3) for this scenario. High growth would generate an 80% increase by 1985 and a 176% increase by 2000, although if an emphasis on new apartments were to be associated with low growth, and on single family dwellings with high growth, these differences could be slightly accentuated.

This section implies that on the 1971-75 housing growth trend, the increase in trip lengths (for example, at a weighted average of 27% from Table 4.4) will be fairly modest, and that there will be little scope for constraining urban growth and auto usage. As a conclusion, however, this could be misleading for many reasons. In the first place, there is no necessary reason for future urban growth to follow 1971-75 housing trends; future urban plans and practices may be more compact (or more explosive), particularly as existing plans may have been drawn up before the current energy problems emerged and may be difficult to change in practice. In the second place, there are many potential ways in which future urban auto use can be constrained, for example, greater usage of transit can be induced, either by independent market penetration or in response to auto disincentives to reduce the propensity to use autos in urban areas. Finally, again in response to similar auto use disincentives, there could be considerable potential for urban households to exchange dwellings (via the market) so as to move closer to their work, at least by reducing the directional or peripheral component of their auto work trips (see Fig. 4.3).

Auto Trip Lengths and Speeds in Census Metro Areas (CMA's)

The study of automobile speeds and gasoline consumption in the CMA's may seem to be a separate specialized exercise from the above. But as may be seen below, housing locations seem to be the major determinant of the most important (and most congested) urban work trip lengths. These, in turn, strongly influence the type of highways on which work trips take place, the resultant levels of congestion and traffic speeds, and thus fuel consumptions per mile, which are particularly sensitive to the lower trip speeds which occur under congested conditions (ref. 7).

The first evidence in this complex chain of causation comes from the 1975 Statistics Canada Travel to Work Survey (ref. 7). The reported average speeds for trips to work in the 9 largest CMA's (plus Halifax) are given in Table 4.6.

Two points seem significant from the data given in Table 4.6. The first is that these work trip speeds (including stops, etc.) are significantly higher than the overall average peak period speeds sometimes assumed for Canadian cities (20 m.p.h.). The second point is that, in general, the *larger* the city, the *longer* the work trip and the *higher* the trip speed, for example, with fairly good correlation over the range 19 to 28 m.p.h., speed = 12 + 1.5 x trip lengths in miles. These results probably reflect the presence of more arterials and urban expressways in the larger CMA's, allowing higher average speeds, fewer stops, and thus lower per mile fuel consumption than are experienced on ordinary urban roads.

To verify these speeds, four typical peak-hour work trips to the centre were carried out in Ottawa-Hull which, in size and expected rate of growth, happened to be the most typical of the CMA's in terms of weighted averages (see Table 4.4). The average speed for Ottawa-Hull in Table 4.6 was broadly confirmed, mainly because (in spite of substantial central congestion) the trip lengths were so long that little of the work

Table 4.4 CMA Households and Unconstrained Auto Mileage Estimates 1975-1985-2000 — Normal Growth

	YEARS & ESTIMATED HOUSEHOLDS [c] 000's			AUTO MILES TO WORK [a] (millions)			TOTAL INTERNAL CMA AUTO MILEAGE (millions) [b]			% INCREASE IN WORK TRIP LENGTH	
	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975-85	1975-2000
Toronto	925	1500	1830	4850	9780	12950	9420	19000	25170	24	35
Montreal	925	1146	1340	4420	6020	7550	8590	11700	14700	10	18
Vancouver	412	667	950	1940	3770	6260	3770	7320	12170	20	40
Ottawa-Hull	222	325	476	870	1470	2440	1700	2860	4750	15	31
Winnipeg	198	236	275	680	850	1050	1320	1650	2050	5	12
Edmonton	148	296	430	680	1330	2230	1320	2590	4340	19	36
Hamilton	175	225	287	850	1190	1320	1650	2320	2560	9	19
Quebec	150	211	249	480	750	930	930	1460	1800	11	18
Calgary	150	290	415	510	1220	1970	990	2370	3830	24	40
St. Catherines	111	127	168	410	490	700	800	950	1360	4	13
London	104	150	190	370	600	810	720	1170	1570	11	20
Windsor	86	110	163	290	370	660	570	720	1290	7	20
Kitchener	84	129	180	270	470	720	520	910	1400	13	25
Victoria	81	94	133	250	300	470	490	590	920	4	15
Halifax	76	85	102	200	230	290	380	450	570	3	8
Regina	48	60	71	140	180	230	270	350	450	5	10
Sudbury	46	62	102	190	270	510	370	520	990	7	22
Saskatoon	43	60	70	120	180	220	240	350	430	8	12
Chicoutimi	41	50	59	120	150	190	240	290	370	5	9
St. John's	36	51	72	120	180	280	240	350	540	8	17
Thunder Bay	35	50	57	100	150	180	190	290	350	8	11
St. John	34	36	42	140	150	180	270	290	350	2	4
TOTALS	4160	5960	7660	18000	30100	42000	35000	58500	81600	17 [d]	27 [d]

Notes:

a) 1975 actual values, with forecasts derived from Appendix 4B and assuming equal proportions of apartments and single family dwellings.

b) Derived from Table 4.2 and assumption that other internal auto mileage will increase in same ratio as auto mileage to work, which accounts for 43 percent of the total internal CMA auto mileage on this basis.

c) *Sources: Kirkland and Barnard (ref. 7), adjusted to normal growth national estimates, and including future growth outside present CMA boundaries.*

d) Weighted averages in terms of households.

Source: Working Paper No. 9.

trip lengths took place under congested conditions, so that peak hour work speeds tended to be high. To illustrate the process, typical work trips were constructed for Ottawa-Hull (see Figure 4.2) for 1975 and for expected growth to the year 2000 (from Table 4.4) using an approach outlined in the working paper on the expanding city (ref. 7). The work location ring W, the residential location ring R, and the average trip length to work (8.1 miles) determined a typical 1975 work trip (from any point Q on the residential ring) as QD. This was carried out at 24 m.p.h. (with only 1 mile carried out at less than 20 m.p.h.), and the extension of the trip by 2.5 miles to Q_1 (to simulate the expected growth in auto work trip length up to the year 2000) was carried out at 36 m.p.h., to give an average speed of 26.5 m.p.h.

The matter of detailed trip speeds is of considerable importance for urban auto fuel consumption, due to its inverse relationship to urban trip speeds below about 35 m.p.h. (ref. 7). Above this speed, auto fuel consumption again tends to rise with speed and increasing wind resistance (ref. 7). These matters are covered in Appendix 4C which estimates urban auto fuel consumption as a function of trip length and speed.

Table 4.5 Urban Growth and Unconstrained CMA Auto Mileage for Low Growth and High Growth Scenarios

Scenario	Number of CMA Households 000's			Weighted Average Increase in Auto Trip Length		Auto Mileage to Work (billions)			Total Internal Auto Mileage (billions)		
Year	1975	1985	2000	1975-85	1975-2000	1975	1985	2000	1975	1985	2000
Low Growth	4,160	5,750	7,200	11	24	18.0	27.6	38.6	35.0	53.7	75.1
High Growth	4,160	6,390	8,630	18	33	18.0	32.5	49.6	35.0	63.0	96.5

Source: Working Paper No. 9.

Table 4.6 CMA Auto Trip Lengths and Speeds to Work 1975

CMA	Average Work Trip Length (miles)*	Average Trip Time (minutes)	Average Trip Speed (m.p.h.)
Toronto	10.9	23.0	28
Montreal	9.9	22.0	27
Vancouver	9.8	21.5	27
Ottawa-Hull	8.1	18.5	26
Winnipeg	7.0	19.5	21
Edmonton	7.8	20.0	23
Hamilton	10.2	22.0	28
Quebec	6.6	15.5	25
Calgary	7.0	19.0	22
Halifax	5.7	17.5	19
Weighted Averages	9.0	19.5	27

Note: * Mean of auto with and without passenger

Source: Working Paper No. 9.

Future Trends in Auto Gasoline Consumption as a Function of Growth, Highway Investment, etc.

The estimation of changes in speeds and fuel consumption to be expected from the future growth of auto mileage in CMA's is a difficult and controversial task, even before estimates or assumptions are made of future desirable and actual highway investments. The cross-sectional data in Table 4.6 and the future growth example in Figure 4.2 suggest that auto speeds will rise and that (other things being equal) mileage per gallon will *rise* as CMA's grow. However, it must be noted that the necessary contribution of past and future highway investment (particularly expressways which are more energy saving than ordinary highways, ref. 7) in this process is very uncertain. The experience from Britain, where congestion is a more serious problem and has been researched for many years, suggests that even with little urban highway investment, predictions of very serious congestion have not been fulfilled (ref. 22), presumably because auto users have been able to adjust their behaviour in response to congestion on so many margins. Still another diagnosis could reasonably hold that in the absence of heavy highway investment, "backward bending" relationships (ref. 23) would result, with diminishing speeds *and* traffic flows and higher gasoline consumptions per mile, until complete paralysis sets in. In these circumstances, the safest assumption (hopefully with the balance of probability and common sense on its side) seems that in view of the forecast increases in auto mileage in the higher growth CMA's in Tables 4.4 and 4.5, unless highway investments keep reasonable pace, auto speeds will tend to fall and gasoline consumptions rise over what they would otherwise be. The question of further urban highway investments raises difficult issues and decisions, including the dangers of stimulating even further auto use and vehicle mileage via the travel time budget theory. This, on historical and cross-sectional evidence, suggests that auto trip-makers tend to travel for a constant time per day, increasing their trips and trip lengths with highway investments and higher speeds, and reducing them with increasing traffic and congestion (ref. 24 and 25). However, this theory seems of lesser weight than the more concrete forecasts of considerable auto traffic increase in Tables 4.4 and 4.5. The dangers of activating this expansion of individual travel can be minimized by concentrating on peripheral (circumferential) highway investments, by avoiding investment in radial routes leading into the fringe rural areas, and by planning policies aimed against *exurban* sprawl. The question of further substantial urban highway investment therefore still seems to deserve consideration by the appropriate agencies.

The Future Role of Transit

In 1975, urban transit (mainly in the form of urban buses) appeared to have a clear energy advantage over the urban automobile, averaging approximately 88 passenger miles per gallon (ref. 21, 16 passengers x 5.5 m.p.g.), as compared with approximately 24 passenger miles per gallon (1.4 occupants x 17 m.p.g.). However, if the more economical urban automobile fleet can achieve 34 m.p.g. by end-century (as per normal growth Scenario 2), and urban occupancy remains the same (greater carpooling possibly being off-set by the effect of smaller households and higher car ownership), the urban auto fleet may achieve 45 passenger miles per gallon by end-century, with little differential between urban car and bus for indirect energy requirements (ref. 26). The question arises, therefore, as to how far urban transit and its use can be expanded at the expense of a declining energy productivity before it loses its energy advantage over the urban automobile. In terms of long term effects, i.e., those affecting capital investments in fixed route systems, about 45 passenger miles per gallon seem to be the appropriate urban rate.

Adopting a marginal approach to the expansion of urban transit, it is useful to lay out the national data (ref. 27) on urban bus and rail-car mileage, ridership and subsidies for 1971-75 as in Table 4.7.

The diminishing returns aspect to expanding transit service and use is illustrated in Table 4.7 and may be expressed in

Figure 4.2 Representative Auto Work Trips Ottawa-Hull 1975 and 2000

Source: Working Paper No.9.

two ways. The increase in deficit per additional passenger carried over the period 1971-75 works out at 87 cents (or about 20 cents per passenger mile, justifiable on congestion grounds, etc., see above), while the additional passengers carried per additional bus mile are 2.25. With an average trip length of 4.4 miles, this suggests that the marginal increase in bus use was taking place at an occupancy of 10 passengers per bus, giving a marginal fuel efficiency of about 55 passenger miles per gallon, somewhat greater than the level to be expected from the more economical automobile. This suggests that in the long run, urban transit will be able to hold its market share of urban trips without becoming less energy efficient than improved automobiles.

This tendency toward diminishing returns with the expansion of transit services and use can be illustrated by two further examples. The first is an almost unique success story in the Ottawa-Carleton region in increasing transit ridership by 77% from 1971-76 (ref. 7), by the subsidized expansion of services (particularly express bus services from residential areas to the centre) and other measures such as pricing and control of central parking, and flexible working hours, to achieve a 20% share of all vehicle-based trips and a 37% share of work trips, apparently the highest in the nation (see Table 4.3).

This success story has also been achieved by diminishing load factors, and energy productivity levels, and mainly by attracting peak hour work trips to the centre. For while passenger mileage increased from about 122 million in 1971 to about 235 million in 1975, bus revenue mileage increased from

Table 4.7 Urban Bus and Rail Mileages, Number of Riders and Deficits on Canadian Urban Transit 1971-75

Year	Annual Bus & Rail Mileage (millions)	Annual Revenue Ridership (millions)	Annual Deficit ($ millions)	Marginal Rate of Deficit per additional rider ($)		Marginal Increase in riders per additional bus mile	
1971	246	971	6.8				
				0.19		5.5	
1972	260	1,048	21.2				
				1.33		0.2	
1973	279	1,051	52.1		0.87		2.25
				1.91		2.38	
1974	292	1,082	111.2				
				0.76		2.05	
1975	329	1,158	168.8				

Source: Canadian Association of Urban Transit, Transit Facts, 1975.

8.8 million to 19.9 million. This equals an overall marginal rate of 10 passenger miles per bus mile (or about 55 passenger miles per gallon) with a marginal rate for 1974-75 of 6.6 additional passenger miles per additional bus mile (or 36 passenger miles per gallon).

Secondly, the successful and generally energy productive expansion of bus transit (exemplified by the Ottawa-Carleton bus system) might approach the bus capacity of surface central street systems, so that if transit shares are to be maintained in expanding medium size CMA's, it will be necessary to consider mass transit systems on separate rights of way, surface, underground and overhead.

This involves difficult choices between express bus and rail, and here the second example of diminishing returns — a comparison between the cost and energy effectiveness of the two modes (ref. 7) — becomes relevant. For a hypothetical CMA of 500,000 population, doubling in households by end-century with 30% of jobs in the CBD, a mass transit system of 28 miles of either mode covering half the area of the city with the aid of bus feeder services could be expected to attract up to 25% of work trips. It would carry a maximum volume of 10,000 passengers per hour in the peak direction and section, increasing to 20,000 passengers per hour as the population grows, provided that the CBD-oriented jobs grow correspondingly. Altogether, the mass transit system would then attract some 12% of all trips, but since half of these would be transfers from ordinary transit systems, the rapid transit system would only serve to hold market share of a doubling in households and jobs.

Comparing 28 mile rail and bus systems, with 10% of track underground, and 10% overhead, tracks would cost at least $225 million or $185 million respectively, and these would require feeder services to attract sufficient passengers to the system so as to use it to capacity and keep capital costs per trip down. Total capital costs (including rolling stock) would be at least $300 million for express buses (with reservations on their ability to handle up to 20,000 passengers per hour centrally on surfaces or underground) and at least $500 million for rail. Total costs per trip at maximum peak hour volumes of 20,000 passengers per hour would be at least $1.25 and $1.50 per trip, or at least 24 to 28 cents per passenger mile. These systems could achieve either a high (theoretical) peak hour energy efficiency of up to about 180 passenger miles per gallon via express and feeder bus, or eliminate oil for line haul via electrified rail at a premium of 80 cents per gallon or $28 per barrel saved.* But a comparison with peripheral (circumferential) expressway investment (even assuming similar track costs averaging about $8 million per mile) and auto use, indicates that the latter would be more cost-effective (though less energy productive) at about 20 cents per passenger mile (6 cents per passenger mile for track and 14 cents per passenger mile for auto use, ref. 20). One reason for this is that in spite of its lower capacity in terms of potential passenger flow and mileage, the expressway (suitably located) could be used for so many more hours in the year (up to 8760 instead of mainly 500 peak hours) that its capital costs per trip or passenger mile are lower than for rail (and similar to bus), whose rolling stock costs are heavy but little used in off-peak hours. Again, auto use normally involves no direct labour costs, whereas labour costs for express buses and feeder buses (for both modes) are considerable, since labour is little used in off-peak hours. However, the cost-effectivness of express buses on busways might be considerably improved if busways could be designed for, and used by, automobiles in off-peak hours.

To sum up, therefore, it appears that no vehicle is ideal for urban transport, the urban auto being cheaper, ubiquitous and flexible, but less energy efficient, congesting in city centres, and with adverse environmental impact. Transit *can* be more energy efficient and cost-effective for heavy volumes of peak hour work trips to, toward, and through the CBD, but tends to lose these advantages with route extension, job dispersal, and idleness or emptiness in off-peak hours.

It is suggested, therefore, that both centre-oriented rapid transit systems (aiming to hold market shares while remaining energy efficient) and circumferential expressway and arterial investments (preferably with relatively low speed limits, 30-40 m.p.h.) must be considered to accommodate dispersed auto trip growth for CMA's of appropriate size and growth. For example, Vancouver, Ottawa-Hull, Edmonton and Calgary seem to be in this category, with appropriate modifications in the balance of transit and highway investments for larger and smaller CMA's. The major problem, however, seems to be Toronto, whose size and expected growth (within and outside its present boundaries) seem to present special problems in planning, growth, transit and highways (see Table 4.4).

Wider Considerations and Summing Up

So far in the strict transport sense, this chapter has suggested similar general urban conclusions on basic and on growth grounds, that the most cost-effective mode for peripheral circumferential trips is the automobile whilst the

* But in terms of BTU's/passenger mile rail would have half the direct energy consumption of bus (ref. 26) with similar indirect energy requirements.

most cost-effective mode for centre-oriented peak-hour trips is transit (in the form of express buses on busways if central capacity problems can be resolved) if the full social costs of the urban automobile are included. In growth terms, the most important factor in reducing urban trip lengths and travel seems to be more compact housing development for whole CMA's via possible in-filling, more liberal *urban* planning procedures nearer city centres, and by density, a doubling in overall density tending to reduce internal trip lengths by about 30% (ref. 28). In conjunction with centrally located jobs, higher density will also tend to make cities more transit oriented, although, whilst central jobs still seem to grow with city size, they seem to do so at a diminishing rate as jobs grow more rapidly elsewhere (ref. 7).

However, there are many other potential measures which may be taken in urban areas to make auto use more efficient (and/or restrain auto use to where it is the most cost-effective mode) which collectively may be significant. Some of these are (ref. 25 and 29) transit priority on highways, improved feeder and distributor transit systems, transit fares more closely geared to quality of service, services to disadvantaged (via para-transit), auto-free or auto-restricted central zones, parking charges and management, improved taxi service (via greater freedom of entry, for example), car or van-pooling, greater mixtures of land uses in zoning and subdivisions, concentrations of development at nodes or in corridors, more flexible working hours and controls on exurban developments.

Appendix 4A — The Locations of Dwellings and Trip Lengths to Work

To estimate the distribution of dwellings in terms of straight line distance from city centres was a difficult task with the time and resources available. It was impossible to analyze the 1971 census results for distance of dwellings from centres for all CMA's, and proxy methods had to be used. These consisted of analyzing the 1971 distribution of population of each census metro area (ref. 7) (as a proxy for the distribution of workers' dwellings in 1971) by assuming that the areas of highest population density were located at city centre, and that progressively lower density areas were located in concentric rings at progressively increasing distances from the centre, determined by the cumulative application of πr^2. For example, 31,000 people living at a density of 10,000/sq. mile would be allocated to a ring 0-1 mile from the centre, 47,000 people living at a population density of 5,000/sq. mile would be allocated to a ring 1-2 miles from the centre and so on.

In outlining this complex process, it must be stated that it involved many minor errors (for example, assumptions of circularity, concentricity, and compactness) which result in underestimation of straight line distances to centres, and which could be resolved at this stage only by reconciling with actual data on auto work trip length, and by cross-checking with other independent sources and data.

The results of this exercise were reconciled with 1975 travel to work data from Statistics Canada (available for 10 CMA's) and the results are given in Table 4.8.

From Table 4.8 (illustrated in Figure 4.3), it is possible to establish a fairly good correlation between estimated average straight line distance of dwelling from CMA centres, and the actual average auto trip length to work. The only exception is Hamilton which may operate as part of Toronto in terms of travel to work. The following equation (1) results:

$$L = 3 + 1.35\, D_c \quad \text{(approximately)} \text{------------------------}(1)$$

where L = average actual auto trip length to work in miles
D_c = average straight line distance of dwellings from CMA centre in miles

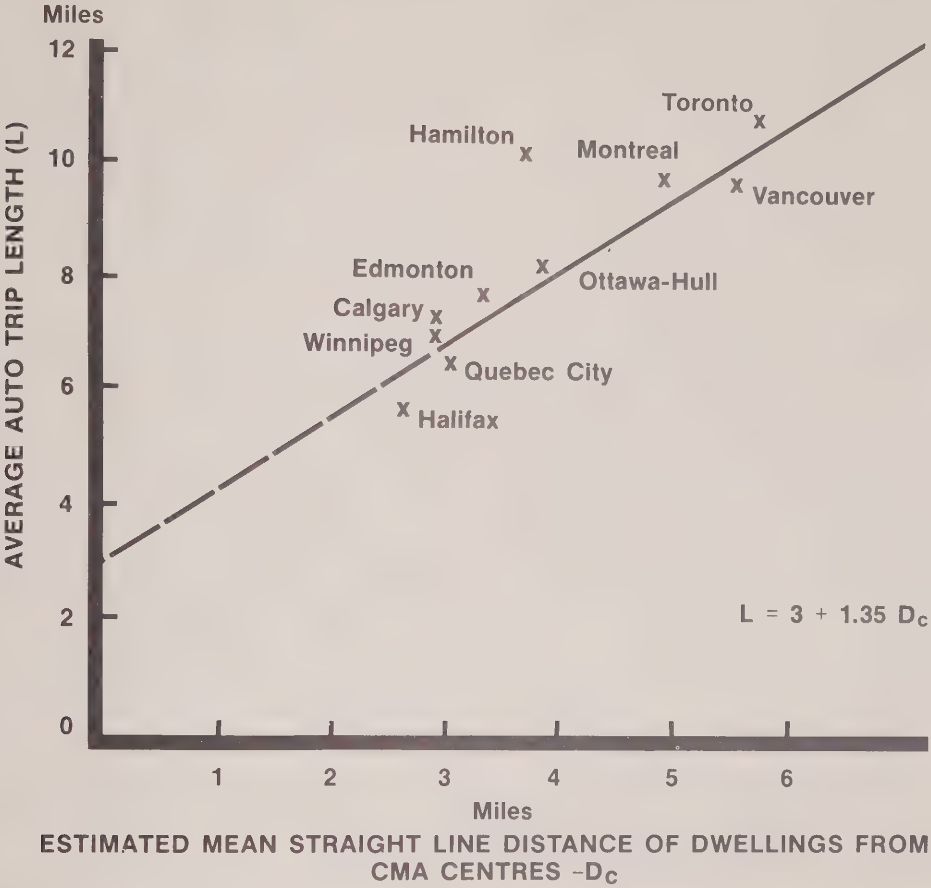
The terms of this equation can be explained as follows. The constant 3 seems to be explained by the fact that even for those living in CMA centres, the average trip length by all modes must have a minimum positive value (ref. 7). Also, the automobile tends to be used for the longer and more dispersed trips to work than are other modes (ref. 20) and, in addition, there may be some underestimation of D_c. The coefficient (1.35) can be explained by the road network factor which means that (irrespective of type of road network) average distances will be about 1.25 times straight line distances (ref. 7), together with the previously noted underestimation of D_c.

Table 4.8 Estimated Mean Distance of Dwellings from Centre and Auto Trip Lengths to Work for 10 CMA's 1975

CMA	Estimated No. of Households 000's	Estimated Population 000's	Estimated Average Straight line Distance of Dwellings from Centre (miles)	Average Auto Trip Length to Work (miles)
Toronto	925	2,750	5.8	10.9
Montreal	925	2,800	4.9	9.9
Vancouver	412	1,150	5.5	9.8
Ottawa-Hull	222	640	3.8	8.1
Winnipeg	198	580	2.9	7.0
Edmonton	178	560	3.3	7.8
Hamilton	175	530	3.7	10.2
Quebec	150	510	3.0	6.6
Calgary	150	480	2.9	7.0
Halifax	76	220	2.6	5.7

Source: Working Paper No. 9.

Figure 4.3 Estimated Mean Dwelling Distances from CMA Centres and Auto Trip Lengths to Work, 1975



Source: Working Paper No. 9.

Appendix 4B – Unconstrained Auto Usage as a Function of Household and Housing Growth

Broad cross-sectional comparisons of auto mileages per household between urban areas of widely different sizes (as given in Table 1.2) imply that internal urban auto mileage per household falls with the growth of a given CMA. However, a more relevant and accurate cross-sectional comparison between the 22 CMA's (from the data given in Table 4.1) indicates that average auto trip length to work (in miles) is given approximately by $3 + 0.75\ H^{0.35}$ where H is a number of households in 000's. This suggests that a doubling in households, for example from 200,000 to 400,000, would lead to a 27% increase in auto trip length to work and an increase of auto work trip mileage to 2.55 times the original level. However, a cross-sectional approach is too deterministic for forecasting (or policy) purposes, as there is no obvious reason for a city to grow in the same way as a city of similar size has done in the past, and a longitudinal (or time series) approach is preferable. To do this, the estimated average distances of dwellings from their CMA centres in 1971 (as estimated by the approximate methods used on the 1971 census data) were compared with the estimated average distances from centres of new dwellings built from 1972-75 and with the percent increases in housing stock over this period (ref. 7). Because of the lack of municipal detail in housing completions data (particularly for the smaller, less important CMA's), the correlation between percent increase in mean dwelling distance and percent growth in housing stock was extremely poor when calculated for individual CMA's.

However, for the 22 CMA's as a whole, the weighted average distance of dwellings from CMA centres seems to have increased from 4.0 miles in 1971 to 4.4 miles in 1975, while the total number of CMA households and occupied dwellings increased by about 18%. This suggests the following general equation (2) for average CMA auto trip length to work (AATW) in miles:

$$AATW = 3 + 0.24\ H^{0.55} \quad \text{(approximately)} \text{ ------------- } (2)$$

where H = number of households in 000's

This suggests, for example, that a doubling in households from 200,000 to 400,000 would increase average auto trip length by about 31% on the 1971-75 trend, and would increase

average auto mileage to work to 2.6 times its original level if the propensity to use auto to work remained the same, a similar result to that from cross-sectional comparison. However, the growth in CMA dwellings for the 1971-75 period consisted of 48% apartments (ref. 7), with a weighted average distance of 5.0 miles from their centres, and 52% other dwellings (37% single family and 15% two-family and row), with a weighted average of 5.9 miles. This variation in distance and trip length with dwelling type may be most simply handled by weighting future households for type of dwelling accordingly, with a weight of 0.85 households for apartments, 1.20 households for single family dwellings, and the intermediate value of 1 for intermediate types of dwelling such as row housing and duplex, which could not be located with any accuracy from the 1971-75 completions due to their small numbers and lack of municipal detail. In these terms, the future proportion of row housing will have no effect on equation (2), which will be applicable provided that the proportions of apartments and single family dwellings are approximately equal, as they were in 1976 housing starts, for example.

As an example of the effect of dwelling type (with the 1971-75 housing growth trend) on auto trip length to work, a doubling in households entirely comprised of single family dwellings would increase weighted average CMA auto trip length to work by about 37%, while a doubling in households entirely in apartments would increase it by 25%. Similar weighting techniques to these may be used to simulate more or less future compactness and constraint (for all new dwelling types), than was the case in the 1971-75 housing growth trend, which is not, of course, inevitable for the future.

Appendix 4C — Gasoline Consumption as a Function of Auto Trip Speeds and Lengths

Some United States research (ref. 7), (based on tests in Detroit at 0°C to 20°C, and therefore fairly representative of the warmer, more populated parts of Canada) seems to have analyzed this matter in a manner relevant to Canadian conditions.

Tests were conducted on 6 automobiles (sub-compact, intermediate and standard) ranging in weight from 2,275 pounds to 5,460 pounds. The most representative (median) automobile in the test and the most representative (median) category of the 1975 Canadian auto fleet was the intermediate size car, weighing 3,800 pounds, with automatic transmission. The research analyzed urban fuel consumption into three basic elements: vehicle weight (and thus gasoline required to overcome rolling resistance, etc.), the warming-up process (and thus the extra gasoline required), and journey time per unit distance (related to idling fuel consumption). For the intermediate size car, using a variety of drivers and driving techniques, and assuming a mean temperature of 10°C (50°F) gasoline consumption per mile in terms of these three elements in sequence (but converted to more conventional units) was as follows:

$$GPM = 0.030 + \frac{0.12}{D} + \frac{0.37}{V} \quad (3)$$

where GPM = gasoline consumption in Imperial gallons per mile

D = trip length in miles $\left(\frac{0.12}{D} \leq 0.04\right)$

V = overall trip speed in m.p.h. ($V \leq 35$ m.p.h.)

For an 8 mile trip at 10°C at various hypothetical speeds, this equation yields the results given in Table 4.9 in the more familiar terms of miles per gallon.

These results imply a typical urban auto fuel consumption of about 17 miles per gallon at 24-27 m.p.h. (See Table 4.6), which seems consistent with independent estimates (ref. 21).

It may also be noted from equation (3) that, due to the warming up process, fuel consumption (at 27 m.p.h., for example) ranges from about 12 miles per gallon for trips of 1-3 miles in length to about 18 miles per gallon for trips of 10 miles, indicating that most of the additional fuel required for warming up is consumed in the first three miles. This reinforces the tendency (via speeds) for average gasoline consumption per mile to fall with urban trip lengths.

Table 4.9 Estimated Gasoline Consumption as a Function of Overall Urban Trip Speeds, Intermediate Auto, Cold Start from 10°C (50°F) 8-Mile Trip

Average Trip Speed (m.p.h.)	Gasoline Consumption (Gallons per mile)	(Miles per gallon)
5	0.119	8.4
10	0.082	12.2
15	0.070	14.3
20	0.064	15.7
25	0.060	16.7
30	0.057	17.5
35	0.055	18.0

Chapter 5 — The Automobile, its Current Role, Cost-Effectiveness and Energy Productivity for Inter-City Trips as Compared with Other Modes

The Role of the Automobile and other Modes for Inter-City Trips

To give a cross-section of inter-city trips (over about 25 miles) by automobile and other modes is a difficult task because of the problems of identifying and recording many trips between many discrete points over a wide range of trip lengths.

However, to give a very general picture and example of inter-city trips (between 94 cities covering the almost 70% of the Canadian population living in cities over 10,000 population), the distribution of these trips by mode, trip lengths and frequencies can be exemplified as in Table 5.1 and Figure 5.1 (ref. 30).

It may be noted from Table 5.1 and Figure 5.1 that the inter-city travel market is dominated by the automobile in terms of trips (about 90%), although its dominance is greatest for shorter trips, with an average trip length of about 100 miles for auto (and bus), about 250 miles by rail, and about 850 miles by air. Thus, the automobile only accounted for about 56% of inter-city passenger mileage in 1975, with air accounting for about 30%. It may also be derived from Table 5.1 that, as opposed to very frequent urban trips, the average Canadian only made about 10 inter-city trips a year (of which about 9 were by automobile), so that their knowledge of alternative inter-city modes to the automobile is limited to an average of about one trip per year.

Table 5.1 Estimated Domestic Modal Patronage by Length of Inter-City Trip — 1975 millions

MODE	Up to 500 miles	500-1,000 miles	>1000 miles	All Trips
AUTO	187	2	1	190
AIR	6	2	3	11
BUS	8	1	1	10
RAIL	2	1	1	4
TOTAL	203	6	6	215

Source: Canadian Transport Commission, "A Comparative Analysis of Strategies For Inter-City Passenger Transport in Canada", Canadian Transport Commission Research Branch, 1976.

The Cost-Effectiveness of the Automobile in Relation to Other Modes for Inter-City Trips

To examine whether the kind of modal distribution shown in Table 5.1 and Figure 5.1 represents the most appropriate use of the automobile and other modes for inter-city trips, it is necessary to examine the cost-effectiveness of the automobile in relation to other modes, with the general aim of meeting demand or needs at minimum total costs, at prices, taxes or costs which reflect total modal costs as closely as possible or desirable (ref. 30).

This is a difficult task, with the problems ranging from a choice of methods, through problems of data on passenger flows, modal costs and passengers' time valuations, to problems of presentation of a complex controversial subject in a simple, general, comprehensible way. But using cost-effectiveness methods, considering only general applications to given passenger volumes and trip lengths, it is possible to bring out the appropriate roles for the automobile in relation to other modes fairly clearly and simply. However, since there are several unknowns (or unknowables, such as passengers' time valuations, see below), it is only possible to be "broadly right" rather than "precisely wrong", and it is hardly worth pursuing accuracy in these costs to less than ± 10 %, particularly as this section of the study is comparative rather than absolute.

In considering cost-effectiveness methods and comparisons between modes, there are three basic elements of costs to be considered for any valid comparison: the delay to passengers before the next trip (negligible in the case of the automobile), the full modal costs (direct, indirect and infrastructure) of the vehicle carrying out the trip, and passengers' time costs en route. Given that passengers wish to travel in an even spread over a 16 hour day, these elements of cost for the public modes (air, bus and rail) may be generally written as a basic equation:

$$C = \frac{16PT}{2Q} + QML + \frac{PLT}{V} = \frac{8PT}{Q} + QML + \frac{PLT}{V} \text{ ---------- (4)}$$

where C = total trip costs per day (waiting, modal costs, and travel time)
P = given number of passengers wishing to take trip by mode over a 16 hour day
T = passengers' average time valuations in $ per hour
Q = frequency of vehicle trips per 16 hour day
M = full inter-city costs per vehicle mile of mode (direct, indirect and infrastructure costs)
L = given trip and stage length in highway miles
V = average door to door speed of mode in m.p.h.

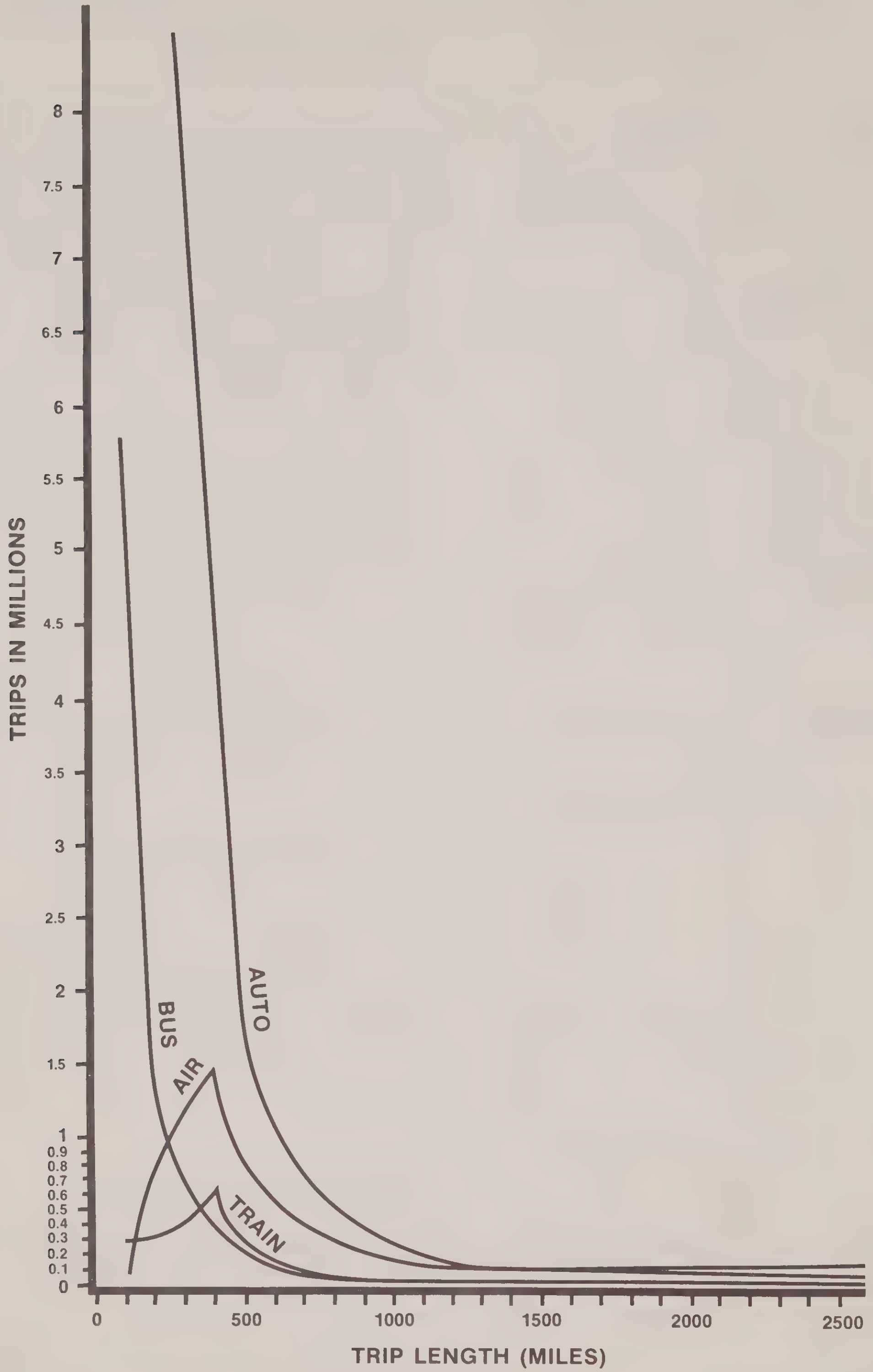
This total cost equation may be used theoretically to minimize the total costs of each public mode, but practical considerations (for example, vehicle sizes and indivisibilities) inhibit this. Therefore, this equation must be used more practically for existing equipment with a view to identifying the various elements of cost and thus the total costs of each mode for given passenger volumes and trip lengths (ref 30). The detailed costs and results from working out this basic equation for the various modes (auto, air, bus and rail) are given in Appendix 5A.

Times and Distances to and from Terminals and Other Matters of Comparison

Assuming that trip lengths are measured centre to centre (and that passengers would really wish to travel centre to centre), some comparatively small but very complex problems are the excess distances that must be travelled usually at the origin by each mode, and their times, for the purposes of general rather than specific study.

Since most passenger trips are home based, it is possible to use the data underlying Chapter 4 and other data (ref. 28) to estimate typical excess distances over centre to centre distances at the origin for each mode. Thus, the average excess

Figure 5.1 Distribution of Intercity Trips by Distance



Source: Canadian Transport Commission, "A Comparative Analysis of Strategies For Inter-City Passenger Transport in Canada", 1976.

distance by automobile may be estimated at about 1.5 miles, the excess distance to a central bus or rail station at about 6 miles, and the excess distance to and from airports (occurring at both origin and destination) at about 13.5 miles (ref. 30). However, since these trip times at the origin are usually less than (and included in) the intervals between vehicles, and have therefore already been valued by the methods above, the only substantial differentials for comparatively long trip lengths are the terminal penalties of airports, at up to about 27 miles extra distance (3% of average trip length) and about $^3/_4$ hour in excess trip time.

These terminal penalties against the air mode, however, are likely to be generally more than outweighed by shorter air line distances than those for the other modes. Analyzing this matter, it was found that whilst the average highway distance between the 231 city pairs formed by the 22 CMA's was 1,835 miles, the average distance between these pairs by air was about 1,400 miles, only 76% the highway distance*. On a smaller more relevant scale, the average air distance between Toronto and the remaining 21 CMA's (at about 800 miles) was again about 76% of road distances, whilst for rail (on assumptions favourable to rail), air distances were 82% of weighted average rail passenger route distances. To cover this differential generally, therefore, the terminal disadvantage of air may be eliminated, its remaining distance advantage set against the 17% mark-up required to cover infrastructure deficits (see Table 5.5 Appendix 5A) and air costs assumed to apply to road/rail distances.

Another difficult matter is the problem of estimating trip speeds and costs for the various modes for such long trip lengths, principally because of the problem of intermediate stops and overnight costs. To allow for these, and roughly dispose of the possible additional costs of meals and hotels en route, all modal trip speeds have been conservatively estimated (400 m.p.h. for aircraft and 40 m.p.h. for other modes) and $10 per passenger added to auto, rail and bus for trips over 500 miles. Similarly, the social costs of each mode (air pollution, noise, etc.) have not been covered in this chapter, but for inter-city travel with low population densities en route, these should be comparatively small. Assuming the inclusion of accident costs in auto costs (see Table 5.3 in Appendix 5A), the only other social costs to be noted for inter-city travel are the costs of congestion imposed on others on the urban portions of inter-city trips (which should be comparatively small), and airport noise. For the 5 international airports (in Montreal, Toronto, Vancouver, Ottawa and Edmonton) about 1% of their total populations were exposed to upper excess noise levels, 3% to intermediate and 5% to lower excess noise levels (ref. 34).

Results of Cost-Effectiveness Comparison Between the Automobile and Other Modes

The equations developed above may be applied to a cost-effectiveness comparison between modes over a range of trip lengths up to 1,000 miles and over a range of passenger flows up to 1,000 per day, where the scope for modal choice and comparison are greatest. Rather than present a complex and detailed matrix for all modes, the results are summarized in Figure 5.2, which shows the ranges of trip lengths and passenger volumes in which the different modes are *potentially* the most cost-effective, that is, show minimum total costs for the passengers and trip lengths indicated. Unfortunately, with 1975 equipment and costs, passenger rail does not figure in the comparison, although it could do so with more modern equipment, higher speeds and lower costs, probably to occupy a position somewhere between bus and air. Subject to this proviso, however, from the results in Figure 5.2 (which are indicative rather than conclusive) the automobile in total seems the most cost-effective mode only up to short trip lengths (100 miles) and low daily passenger volumes (100 per day), although these trip lengths and volumes may account for a large proportion of inter-city trips (see Table 5.1 and Figure 5.1 above). From trip lengths over 100 miles with more than 100 passengers per day, up to trip lengths of 400-500 miles, the bus seems to be potentially the most cost-effective mode, above which air tends to be the minimum total cost mode. The bus, however, has only a slight total cost advantage over the automobile in this area, its total costs never being less than 80% of those of the automobile on the occupancies and time costs estimated, with a similar trip length and total cost structure to the automobile (see Appendix 5A).

Perhaps the most striking result of this cost-effectiveness comparison, therefore, is the result of calculating automobile costs to include gasoline and time costs only, equal to 60% of total automobile costs (see above). The area in Figure 5.2 over which the automobile then appears potentially the most cost-effective mode increases substantially, and inter-city passenger transport seems to polarize between the automobile for trips up to 500 miles (i.e., the auto's daily range), and the air mode for longer trips of higher volume, as it tends to in Table 5.1 and Figure 5.1.

The perceived cost factor suggests that the cost structure of the automobile should be changed so as to express its full total costs per trip as closely as possible, mainly by expressing its full total costs in the form of gasoline prices as far as possible. Apart from vehicle registration fees (which switched to gasoline taxation would increase gasoline prices by about 10%, see Table 5.3), this might be difficult to do effectively because the automobile might become even more gasoline economizing, and the scope for differential pricing of gasoline between Canada and the United States, for example, is obviously limited.

Figure 5.2 also suggests that the bus mode (and possibly modern rail) tends to be submerged by the automobile, that there is a lack of perception by its users of the automobile's full total costs, and that some encouragement to the bus mode is desirable on cost-effectiveness grounds alone. This question will be returned to after the energy effectiveness of the various modes has been considered.

Testing for the sensitivity of the comparisons to the values of time and other variables estimated (and thus the propensities to use modes) it is clear from Figure 5.2 that the most important boundaries on 1975 data are those between the auto and the bus, the bus and air, and the auto and air.

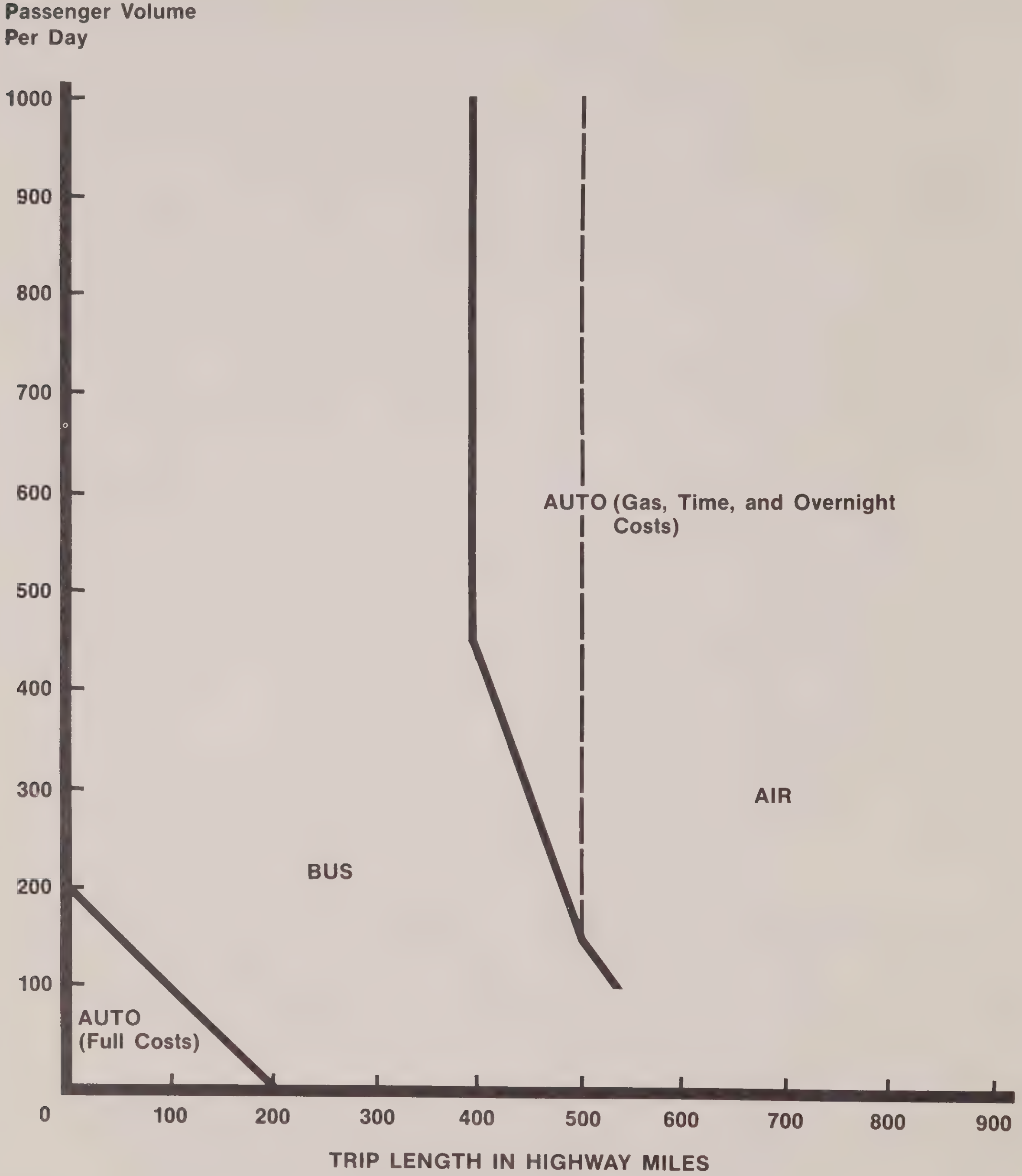
Analyzing these boundaries in turn (ref. 30) the auto/bus boundary is sensitive to time valuations, but even more sensitive to auto operating costs (and user's perception of them), and to auto occupancy, such that at an occupancy of 4 the automobile will achieve complete dominance over the bus regardless of time valuations. The auto/bus/air boundary is also sensitive to time valuations because bus and auto (at gas costs only) are low cost, low speed modes which will gain from low time valuations and lose from high. For example, at a passenger time valuation of $10 per hour, air becomes the least cost mode for trip lengths down to 250 miles.

The Energy Efficiencies and Productivities of the Automobile and other Inter-City Modes

To set the scene on energy perhaps it should be recalled (from Chapter 2), that since the energy problem seems to be mainly one of oil supply, it seems preferable to concentrate initially on oil, and use the concepts of energy efficiency (vehicle miles per gallon, m.p.g.) and energy productivity (passenger miles per gallon, p.m.g.). These seem preferable to using the more abstract BTU, and derivatives such as seat

* This same point on "circuity" was covered at some length by Boeing (ref. 33) on ATA rules for the United States with similar results, a 25% lower distance by air.

Figure 5.2 Potentially Most Cost-Effective Modes by Trip Length and Passenger Volume, Passengers' Time at $3.00 per hour, Auto Occupancy 2.4



Source: *Reynolds, D.J., "Preliminary General Guidelines on Cost-Effectiveness and Energy Productivity of Inter-City Passenger Modes", Working Paper No. 33, Role of the Automobile Study, Strategic Planning, Transport Canada, 1979.*

miles per gallon or load factors which (while useful descriptively) can be misleading as a measure of the useful work performed per gallon of oil by a passenger mode. Because of the air line distance factor mentioned above, all mileages will be in terms of road and rail mileages, and the efficiency and productivity of the air mode raised (in the ratio 1.25) accordingly.

Before current and future estimates of energy efficiencies and productivities are made, perhaps it should be stressed that mainly because of the variety of operating conditions, equipment and load factors, it is difficult to generalize on energy efficiencies and productivities of the various modes, and more specialized work is still required.

Therefore, the estimates in Table 5.1.1 must be regarded as indicative rather than conclusive, and cannot be regarded as more accurate than ± 10%.

This table shows that in spite of the tentative nature of these estimates, there seems little doubt that the bus is presently by far the most energy productive inter-city mode, even though it seems to have little potential for further improvement, unless vehicle sizes and loads can be increased (ref. 30). The present inter-city auto seems to be the next most energy productive mode, with the potential of improving its productivity by end century by up to about 100%. The next most energy productive mode seems to be the present aircraft fleet, with a similar potential of up to 100% for improving its productivity via more energy efficient aircraft, and by larger aircraft sizes and passenger loads. The larger passenger aircraft on heavily trafficked long distance routes seems a possibility by end century (given world market volume), with rapid growth in air traffic (see Chapter 3), large economies of scale, and greater price discrimination to lower fares. Indeed there seems a possibility, in spite of energy problems and costs, that aircraft on the basis of economies of scale and price discrimination to lower fares, will become a mass long distance mode by end-century.

The least energy productive mode at the present time seems to be passenger rail, but with modern equipment, higher speeds and higher passenger loads on heavily trafficked routes, it seems to have the potential to improve its energy efficiency to be comparable to that of the inter-city bus.

The above estimates only refer to the direct oil consumption of the various inter-city modes. If, however, the indirect energy consumption from all energy sources is taken into account for energy production, vehicle production and maintenance and infrastructure construction and maintenance (ref. 36), on a passenger mile and per 150,000 BTU basis, the productivities in Table 5.1.1 would be reduced by up to 33% for auto, 20% for air, 33% for bus and by up to 66% for rail. Since most of the indirect energy supply is from sources other than oil, which are in more plentiful potential supply, it is difficult to know what weight to give to these indirect factors, although they would seem to orient comparisons slightly in favour of air, and slightly against rail, with the comparison between inter-city auto and bus fundamentally unchanged.

The Effect of Gasoline Prices on Modal Operating Costs

Having analyzed the cost-effectiveness and energy-effectiveness of the various modes, and having as a result suggested that gasoline prices for the automobile should be raised (via transfer of taxation) as far as possible, it remains to consider the possible effect of gasoline (and diesel) prices on modal operating costs and the total cost of each mode.

Assuming that the rise in prices has no effect on consumption and use, the maximum effect from a doubling of prices for each mode may be as estimated in Table 5.1.2.

From this table it appears that the effect on the total costs of the public modes of a doubling of gasoline or diesel prices will be fairly small, although the leverage of gasoline prices on automobile costs seems significant, particularly as they are the most visible and immediate cost of auto use, so that the effect of a doubling of gasoline prices on perceived costs could be up to 100%. However, more economical automobiles in response to gasoline prices (see Chapters 2 and 3) will inhibit modal change from the automobile, the price elasticity of demand for gasoline (ref. 25) ranging from around zero in the short run for small changes in price up to about 1 in the long run for larger changes in price. The main margin for adjustment is apparently the gradual substitution of more fuel economising vehicles.

Table 5.1.1 Estimated Direct Energy Efficiencies and Productivities of Inter-City Passenger Modes

Mode	Average Energy Efficiency (m.p.g.) 1975	Average Energy Productivity (p.m.g.) 1975	Forecast Energy Efficiency (m.p.g.) 2000	Forecast Energy Productivity (p.m.g.) 2000	Notes on Forecasts
Inter-city Auto Fleet (2.4 occupancy)	20.00	48	32-39	77-94	High and low technology forecasts with 1975 occupancy.
Air Fleet* (approximate average occupancy 100 in 1975)	0.33	34	0.50	50-75	50% increase in M.P.G., without and with 50% increase in aircraft size and loading.
Bus (approximate average occupancy 22 in 1975)	6.00	130	6.00	150	Little scope for change unless vehicle size increases.
Rail (approximate average occupancy 1975 = 70)	0.40	28	0.50	130	Light, rapid, comfortable train (LRC) of 520 seats and 260 passengers.

* Energy efficiency and productivity increased by 25% to make air mode comparable with other modes.

Source: Chumak, A., "Trends in the Use of Energy in Transportation", Working Paper No. 23, Role of the Automobile Study, Strategic Planning, Transport Canada, 1979.

Table 5.1.2 Gasoline and Diesel Prices and the Effect of Their Doubling on Modal Operating Costs 1975

Mode	Average Modal Costs Per Mile $	Gasoline or Diesel Expenditures per mile $	Maximum % Effect on Operating Costs of Doubling In Prices
Automobile	0.19	0.035	18
Air*	11.00	1.300	12
Bus	1.00	0.110	11
Rail	15.00	1.100	8

* Including passenger costs at $21.43 per passenger.

Source: Working Paper No. 33.

Summary

Summing up this chapter, it has been seen that the automobile has achieved a dominant position in inter-city passenger transport by concentrating on the more frequent shorter trips, although it is being increasingly challenged (from the longer trip end) by aircraft, which might achieve parity in inter-city passenger mileage with the automobile by end-century (see Chapter 3).

The cost-effectiveness comparison between modes (taking account of total costs including the value of passengers' time) shows that at $3.00 per passenger hour, and an estimated average occupancy at 2.4, the automobile is the most cost-effective mode only up to passenger mileages of about 10,000 per day, for example, a 100-mile trip with a flow of 100 passengers per day. From this volume up to trip lengths of 400-500 miles, the bus seems potentially the most cost-effective mode, after which air (or modern rail) becomes the least cost mode.

If, however, users only perceive gasoline costs of operation (or occupancy rises from 2.4 to 3), the automobile becomes dominant up to about 160,000 passenger miles per day (e.g., 400 passengers on a trip length of 400 miles), and tends to submerge bus and possibly modern rail and inhibit their development, the auto/bus boundary being very sensitive to automobile costs and occupancies. The inter-city passenger market then tends to polarise between auto for short trips and air for long as in Table 5.1 and Figure 5.1.

Concerning energy efficiency, by far the most productive modes (in terms of passenger miles per gallon) were the inter-city bus and potentially modern rail, and both on cost-effectiveness and energy grounds there seems a strong case for developing the bus by expressing auto costs more directly to the user, and by more direct measures of aid or encouragement to bus services themselves. For example, unprofitable services by other public modes could be (experimentally) withdrawn for the trips in which bus seems the most cost-effective mode, e.g., up to 250 miles.

This chapter should also consider the question of rural transport which accounts for about 30% of total automobile mileage. However, in view of the even lower concentration and volume of rural passenger flows, it seems that there is even less prospect for other than auto use, although by special investigation and experiment it may be possible to develop further rural bus services, perhaps in conjunction with school buses off-peak. Again the problems of the auto non-user seem to demand deeper and wider investigation.

Appendix 5A — The Total Costs of Inter-City Modes

Time Valuations of Passengers

Starting with passengers' time valuations, the problems of valuing these are so considerable that in spite of much theoretical and practical work over the past 20 years, the only major conclusion of a recent monograph on the subject (ref. 31) was that there was no unique value of travel time (or indeed of any other time), but that it was crudely related to hourly incomes. In these circumstances, the only possibility seems to be to derive a value for travel time from incomes and use it merely as an explanatory variable, testing results for realism, and sensitivity to alternative travel time values.

As a starting point, since few people live, earn or spend in isolation (and can be treated as single person households if they do), it seems preferable to use household incomes rather than individual incomes as a method of derivation to reach a general preliminary value which will apply to all modes for the sake of comparability, and to avoid biassing results toward higher income groups and modes.

Then differentiating between paid workers and others in a typical household, and as travellers, an average hourly value of passengers' time may be calculated for 1974 as in Table 5.2.

As an approximate starting point, therefore, an average value of passengers' time in 1975 of $3.00 per hour may be assumed, and this has the advantage of agreeing (quite independently) with the value assumed in urban areas in Chapter 4. It also approximates the average minimum wage in Canada (ref. 5) and might therefore attain a fairly high degree of consensus for purposes of public policy.

Table 5.2 Estimated Average Value of Passengers' Time (T) For all Modes

Average household income per hour* $ (before tax)	Average household income per hour* $ (after tax)	Average no. of paid workers in household	Average no. of persons in household	Average value of working time $	Average value of other time $	Percent of passengers in working time	Weighted average value of passengers' time $
(1)	(2)	(3)	(4)	1 : 3	2 : 4		
7.25	6.00	0.92	2.98	7.88	2.00	18.00	3.06

* Assuming working year of 2000 hours.

Source: Statistics Canada, Urban Family Expenditure 1974.

Modal Costs (Direct, Indirect and Infrastructure)

The Automobile

For the automobile (since virtually no waiting is involved), its total cost equation may be written:

$$C = \frac{PLM}{O} + \frac{PLT}{V} \text{--} (5)$$

where O = average auto occupancy (estimated at 2.4 for intercity trips)

and the other terms are as given in equation (4).

Since this study is centred on the automobile, which plays a dominant part in inter-city transport, it is necessary to consider the matter of automobile costs in some detail. For this, the most detailed source seems to be data on 1974 urban family expenditures (ref. 4) in the 14 largest CMA's. Reduced to an automobile basis, adjusting for depreciation and interest (at 10%, ref. 20), and up-dating estimates to 1975, the detailed results are given in Table 5.3.

Table 5.3 Estimated Annual Costs (including taxation) of Owning and Operating a Representative Automobile Inter-City 1975

Item	Annual Cost $	Cost per mile* ¢
Depreciation and Interest	$1,190.00	11.90¢
Operation		
Gasoline	333.00	3.33
Oil, Tires and Batteries	50.00	0.50
Repairs not covered by insurance	105.00	1.05
Insurance premiums	140.00	1.40
Registration Fees	30.00	0.30
Other expenditures (garage, parking, washing, tire repair, repair parts, etc.)	47.00	0.47
TOTAL	$1,895.00	18.95

* For an annual average mileage per automobile of 10,000

Source: Urban Family Expenditure 1974, Statistics Canada, 1977

In more itemized terms, the estimates in Table 5.3 produce (as would be expected) a similar estimate of average auto costs per mile (about 19¢), as compared with urban operation. However, the significant points from Table 5.3 are that auto operating costs consist of many items (though principally depreciation and interest), comparatively few of which can be directly and closely related to the operation and trip-making of the vehicle. The only item in this category are gasoline costs at a little more than 3¢ a mile (about 18% of total costs), including 1975 taxation at an average of 33.5¢ per gallon (19¢ provincial, 14.5¢ federal) or slightly more than 1¢ per automobile mile (ref. 20). There is reason to believe that the auto user rationally operates his automobile on a two part basis: a) on trips which can yield large "surpluses" of satisfaction over gasoline costs because of the ubiquity and availability of the auto, and b) setting these total "surpluses" against large "overheads" in deciding on auto ownership.

Concerning automobile costs, the next point to be covered is whether the above costs, which are inclusive of taxation, are adequate to cover the costs of the inter-city road system. Adopting an approach to this problem (ref. 20) aimed at covering the full replacement costs (using a 9% rate of interest) of the existing road system, and differentiating for the costs, traffic volumes and revenues on the urban, inter-city and rural road systems, the results work out as in Table 5.4.

It appears from Table 5.4 that whilst provincial highway revenues only covered about 40% of highway costs as a whole in 1975, the distribution of costs, traffic, and revenues is such that urban revenues at least seem to broadly cover urban infrastructure costs (although not urban social costs, see Chapter 4), and inter-city revenues at least cover inter-city highway costs as a whole. The highway deficit seems mainly attributable to the large, lightly trafficked rural road system which, being mainly for purposes of access, cannot be expected to cover its costs via traffic flows and revenues.

To summarize, therefore, the approximate average full costs of auto operation inter-city, C_c, for a given passenger flow P over a trip length of L miles at an estimated average occupancy (O) of 2.4 at a trip speed (V) of 40 m.p.h., will be given (in $) by:

$$C_c = \frac{PLM_c}{O} + \frac{PLT}{V} = 0.080\,PL + 0.075\,PL = 0.155\,PL \text{-------} (6)$$

where M_c = auto operating costs per mile

However, if the auto user only perceives gasoline and time costs, this sum will be reduced to:

$$0.012\,PL + 0.075\,PL = 0.09\,PL \text{ approximately}$$

that is, to about 60% of full auto costs per passenger mile. In general, there seem to be no economies of scale (in terms of passenger volumes P and trip lengths L) in inter-city auto use, apart from occupancy (O) which obviously has a substantial effect as the reciprocal of operating costs, or users' perception of them (see Fig. 5.2). To these costs must be added overnight costs of $10.00 per passenger for trip lengths larger than 500 miles.

Table 5.4 1975 National Distribution of Costs, Traffic Volumes, Revenues of the Highway System

Category of Highway	% of Highway Mileage	% of Total Costs	% of Vehicle Mileage and Revenues	Total Costs $ (millions)	Total* Revenues (millions)	Ratio Revenues/ Costs
Urban	10	22	59	1,056	1,135	1.07
Inter-city	2	4	10	192	192	1.00
Rural	88	74	31	3,552	597	0.17
Total	100	100	100	4,800	1,924	0.40

**provincial revenues only from "Nation on the Move", RTAC, 1975*

Sources: Haritos, Z., "Rational Road Pricing Policies in Canada", CTC, 1973, and subsequent estimates, plus gasoline taxation and license fees for all vehicles.

Table 5.5 Total Transport Costs and Deficits by Mode 1975 $ (millions)

Mode	Infrastructure Costs	Vehicle Costs	Total Modal Costs	Total Deficits	Deficit as % of Vehicle Costs
Air	517	1,891	2,408	325	17
Road (all vehicles)	4,796*	27,686	32,482	1,992	7
Rail (passenger & freight)	941	2,463	3,404	1,025	42

*The definition of costs employed here is more comprehensive than that used in Table 1.1; for more detailed breakdown of road costs see Working Paper No. 2.

Source: Estimates by Principles, Pricing and Finance Division of Strategic Planning Group, Transport Canada on more comprehensive but less detailed basis than Table 5.4.

Air

Turning to the most heavily used inter-city public mode, air, the situation is complicated by the wide variety of aircraft, sizes, and stage lengths and by the difficulties of ascertaining the full and detailed costs per aircraft mile, which should ideally be built up from a great deal of detailed work. However, analyzing the costs of various aircraft types and stage lengths over the 200-1,000 mile range, it was possible to establish a general cost formula for 1975 for direct and depreciating costs in $ per aircraft mile as:

$$M_A = 2 + 0.32\,S \quad (7)$$

where S = no. of seats (ref. 30)

Via air trip lengths, these costs will cover the mark-up on modal costs required to cover infrastructure costs as in Table 5.5. Adding the costs of passenger delay between flights of passenger time en route (at $3.00 per hour) and adding passenger costs at $21.43 per trip, the resultant minimum total trip costs* ranged from 39¢ per passenger mile (for 100 passengers on 100 mile trips) down to 8¢ per passenger mile for 1,000 passenger miles per day on 1,000 mile trips. This shows considerable economies of scale at an assumed load factor of 66%, optimal load factors for air being higher than for other modes (ref. 30).

Bus

Since the inter-city bus is a comparatively standardized vehicle travelling at comparatively high and standardized speeds inter-city, its costs may be fairly easily estimated (and up-dated to 1975) as approximately $1.00 per bus-mile, considerably lower than that for slower urban operations (ref. 20). Since the inter-city bus seemed to cover its inter-city infrastructure costs via taxation (ref. 32), its full costs can be taken as $1.00 per mile, and constraining average occupancy, P/Q, to 20 passengers (a load factor of about 50%), the cost equation (see equation (4)) in $ for the bus will be given by:

$$C_B = 160T + \frac{PL}{20} + \frac{PLT}{V} \quad (8)$$

Valuing passengers' time (T) at $3.00 per hour, and assuming a trip speed of 40 mp.h., this will become in $:

$$\begin{aligned} C_B &= 480 + 0.05PL + 0.075PL \\ &= 480 + 0.125PL + \text{passenger costs of} \\ &\quad \$10 \text{ for trips over 500 miles} \quad (9) \end{aligned}$$

The resultant total costs will range from about 17.5¢ per passenger mile for a daily flow of 100 passengers and a trip length of 100 miles, to 13.5¢ per passenger mile for a daily flow of 1,000 passengers over 1,000 miles. Because of its smaller size and lack of economy with stage length, the inter-city bus (unlike air) does not seem to have strong economies of scale.

Rail Passenger

For rail passenger, because of the difficulties in allocating comparatively large infrastructure costs (see Table 5.5) between a comparatively small volume of passenger, but large freight traffic, the concept of "avoidable" costs is used. This may be defined as the expenses that would no longer be incurred if a carrier ceased to operate a passenger service, after allowing a reasonable period of time for adjustment to the new condition, and may be regarded as representative of the full costs of rail passenger operation (ref. 30) in its particular context.

Turning to rail passenger costs with existing equipment, on this basis it seems that for low passenger volumes (up to 300 passengers per day) and shorter distances (up to about 300 miles), the most economical pattern of operation is via self-propelled rail diesel cars (RDC's), with multiple unit operation as required (ref. 30). Their 1975 costs in $ per mile may be generally estimated as:

$$M_R = 2.25 + 0.16\,S \quad (10)$$

where S = no. of seats

while for conventional trains for longer trips and large passenger loads, 1975 costs were generally estimated as (ref. 30):

$$M_R = 5 + 0.04\,S \quad (11)$$

Adding passenger costs for delay between trains and passenger time en route, and passenger costs at $10 per trip over 500 miles, the resultant minimum total costs ranged from 25¢ per passenger mile for 100 mile trips with 100 passengers per day, down to 19¢ per passenger mile for 1,000 mile trips with 1,000 passengers per day at an assumed 50% load factor. These costs could be reduced, however, by modern equipment moving at higher speeds and lower costs at high passenger loads.

* *see equation (4)*

Chapter 6 — The Automobile, Safety and the Environment

Safety

Background Statistics and Trends

In 1975 about 650,000 road accidents were reported in Canada involving personal injury or property damage of over $2 billion. These resulted in 6061 deaths and over 220,000 persons injured. Figures 6.1 and 6.2 show how deaths and injuries were distributed in 1974 by class of road user, indicating that car occupants accounted for 63% of fatalities and 74% of those injured, pedestrians for 18% of fatalities and 8% of those injured, occupants of commercial vehicles (including all classes of trucks and buses) for 10% of fatalities and 9% of those injured, and motorcyclists for 5% of fatalities and 4% of those injured. Cars were involved in accidents resulting overall in 81% of all fatalities and 89% of all injured (ref. 35).

Historical trends of some important indicators of safety are shown in Figures 6.3 and 6.4. It can be seen from Figure 6.3 that the considerable increase in vehicle registrations and in vehicle mileage (as measured by gasoline sales) over the long term have been associated with marked increases in fatalities and persons injured. However, the rates of accidents and casualties per vehicle and per vehicle mile have fallen, and substantially so in recent years (since the mid 1960's). Figure 6.4 illustrates the sustained decline in the fatality rate per hundred million vehicle miles, from a peak of 8.7 in 1964 to 6.7 in 1973; and then the dramatic reduction to a rate of 4.7 in 1976. These reductions have coincided with a marked increase in road safety efforts over the relevant period. Precise contributions cannot be measured but it is felt that notable impacts were achieved from the mid-1960's from government-mandated vehicle safety standards, and improvements to the road and highway network, and the reductions from 1973 have been associated with increased use of vehicle occupant restraints and reductions in speeds.

Injury rates have also fallen since the mid-1960's, though less markedly, consistent with the dominant impact of safety measures being on crash protection, rather than crash avoidance. The classification of "injury" is sufficiently broad that a marked reduction in injury severities may have taken place, while leaving the overall injury rate relatively unchanged. Furthermore, since 1973 a substantial reduction has occurred in the injury rate (by some 22% to 1976), consistent with the predicted impacts of increased use of occupant restraints and reduced speeds.

Assumption of Forecasts

Attempts are made here to forecast accidents and casualties from 1975 to 2000 for each of the scenarios developed in the Role of the Automobile Study. A basic causal relationship is assumed between accidents and casualties and vehicle miles travelled (VMT), and the forecast of VMT made for each scenario will be the major predictor of accidents and casualties. The simple, crucial, assumption is made in the central estimates that rates of accidents and casualties per VMT would remain *constant* in the absence of major safety programmes. The predicted impacts of a number of anticipated such safety programmes on accident and casualty rates can then be measured against the initial forecasts. It is recognized that this simple assumption of constant rates ignores the possible influence on accident and casualty rates of shifts in the distribution of VMT by road type, by age of driver, by trip purpose, by vehicles of different sizes, or a number of other possibly important variables. If information on the incidence over time of such contributing factors were available, their influences might be interpretable in a more disaggregated model of accidents and casualties over time, and might then be incorporated in a more sophisticated forecasting mode. Unfortunately, such information is not sufficiently available. However, where the scenario descriptions include major shifts in the distributions of these variables, attempts will be made below to indicate the likely importance of their influences, by hypothesizing alternative impacts, in a form of sensitivity analysis of the central forecasts.

The forecasting proceeds from disaggregation of accidents and casualties into the road user categories and vehicle types identified in Figures 6.1 and 6.2, and the calculation of the rate of occurrence of each category per VMT. The year 1975 is used as the base year for the forecasts, being the last year for which accident data are available in the required detail. A number of foreseeable countermeasures are input to the "model" by systematically modifying the relationships among VMT, numbers of accidents and casualties in the appropriate categories, in accordance with predictions of the countermeasures' impacts from research or experience. It must be noted that the model includes accidents and casualties involving vehicles other than cars, while the scenario descriptions predict only car VMT. It has, therefore, been assumed that VMT by other vehicles changes at the same rate as does car VMT.

Impacts of Foreseeable Countermeasures

Non-Federal Government Programmes

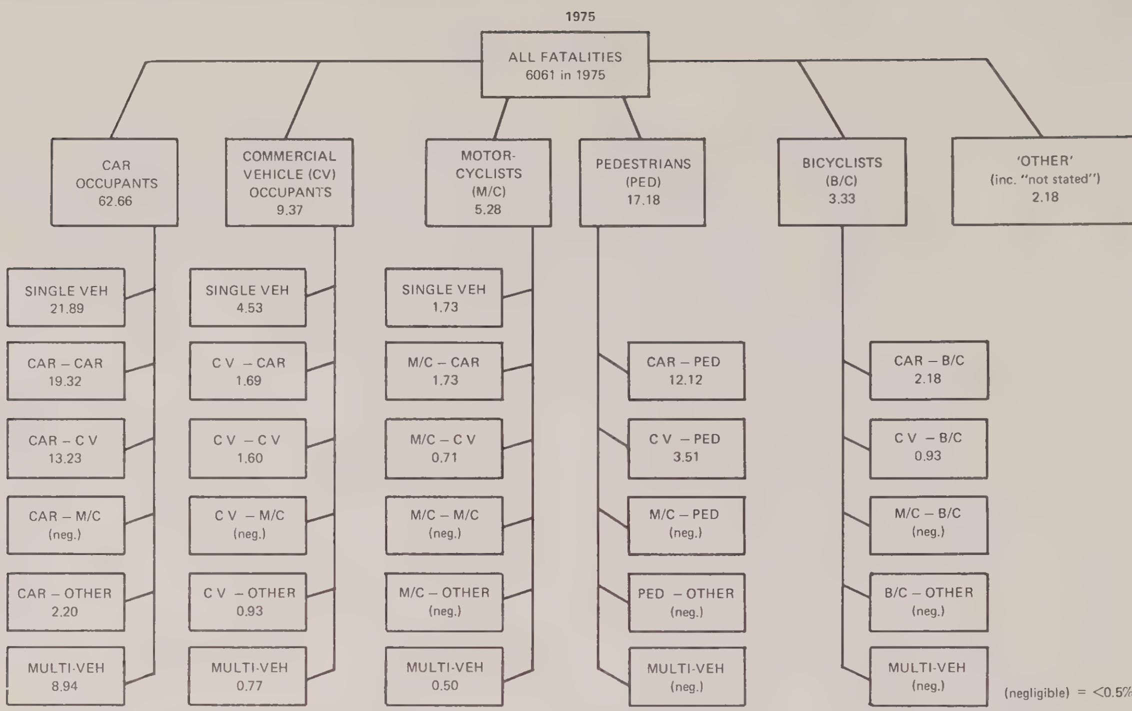
Administrative responsibility for all components of the road safety "system" other than new vehicles lies predominantly with provincial and/or municipal levels of government. Administrative control is exercised through a wide range of legislative and regulatory programmes, governing driver qualifications, conditions of vehicle operation, road user behaviour and its control through enforcement, road user education, provision of emergency medical services, etc.* Such programmes have developed considerably in the last decade, with increasing activity motivated solely by safety evident in extensive programmes of road improvements, road user education, more stringent qualifications for driver licensing, rehabilitation of persistent offenders, motor vehicle inspection, innovative police enforcement procedures, and requirements for use of protective equipment and procedures by road users.

It seems likely that safety programmes of this sort will be pursued with similar vigour in the future. In particular, it seems likely that a major impact will be achieved in the near future by an extension of requirements for use of occupant restraints and requirements for lower speeds, and their enforcement. The impacts of such programmes will be forecast below. In the longer term, it is probable that major efforts will be made to improve safety through increased control of driving while intoxicated, through road improvements (especially roadside hazards removal and other improvements; and possibly through highway construction), and through innovative programmes of road user education. However, the impacts of such relatively remote programmes cannot yet be foreseen, so no predictions of the impacts will be included in the forecasts.

The major immediate future impact on casualty rates is predicted to come from occupant restraint use, supported by reductions in travel speeds. Two alternative reasonable

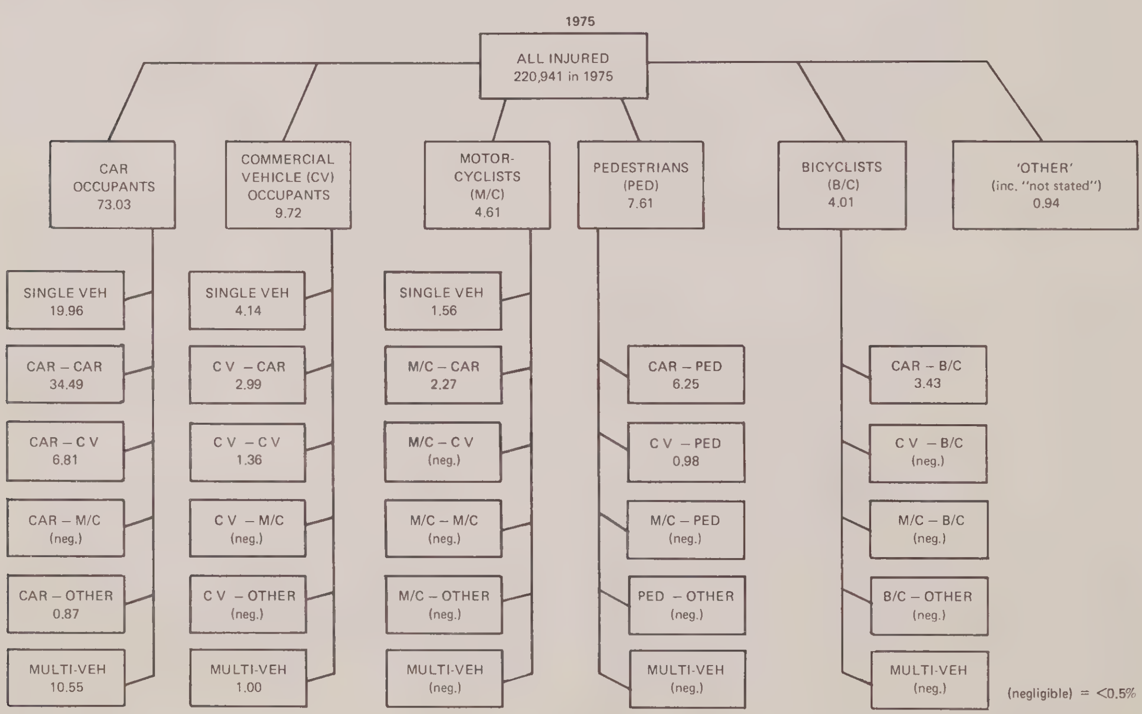
*For descriptions of major existing programmes, see Transport Canada: *Road Safety Programmes – 1974*

Figure 6.1 Percentages of Casualties by Type



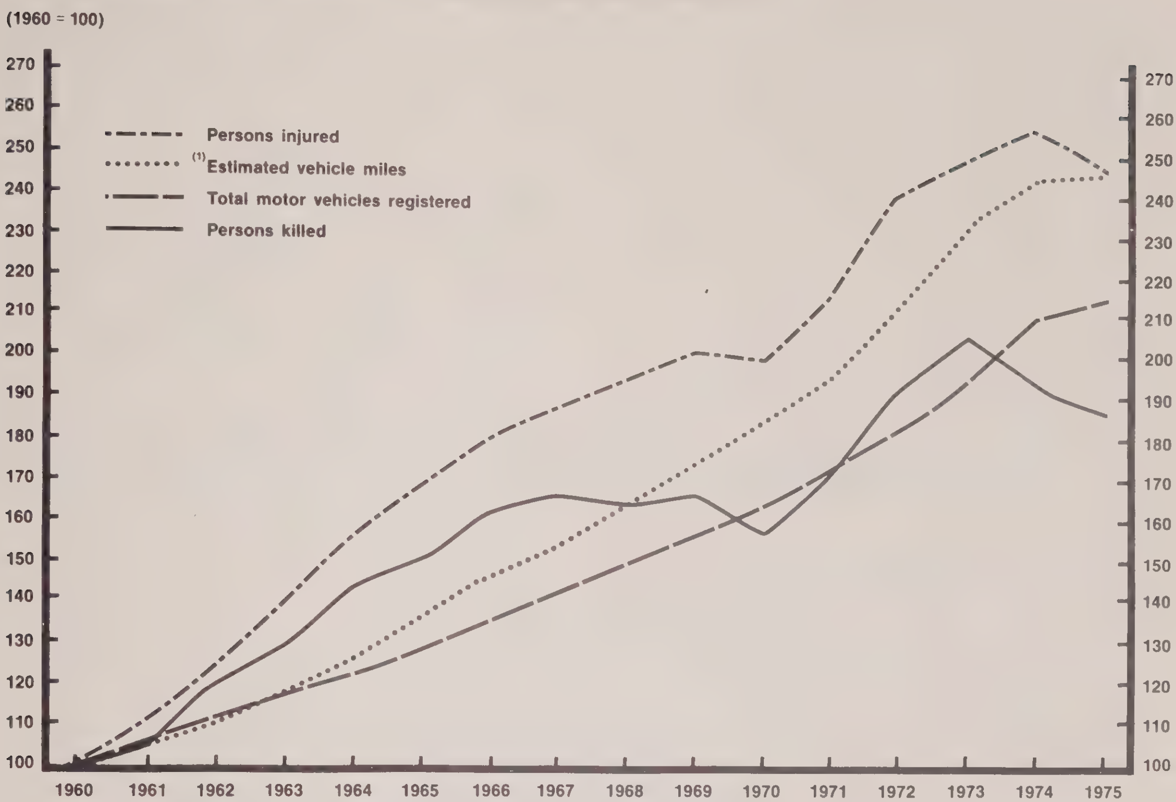
Source: Road and Motor Vehicle Traffic Safety, Transport Canada.

Figure 6.2 Percentages of Casualties by Type



Source: Road and Motor Vehicle Traffic Safety, Transport Canada.

Figure 6.3 Indexes Traffic Deaths and Injuries and Related Data 1960-1975.



(1)Vehicle Miles are based on estimated consumption of petroleum fuels and an estimated mileage per gallon 13.72

Source: Statistics Canada, Motor Vehicle Traffic Accidents, 1975.

assumptions about these will be made in the forecasts:

a) that restraint use reaches 80% in Québec and Ontario where it became mandatory in 1976 and that speed limit reductions are effective in those provinces where they occurred by 1976 (Québec, Ontario and British Columbia).

b) that restraint system use reaches 80% and speed limit reductions are effective nationally.

Impacts of Increased Restraint System Use

A synthesis of research into the effectiveness of restraint systems suggests that, in the population of Canadian accident victims, use of lap seat belts reduces the probability of fatality by 33% and of injury by 27% on average, while use of lap-torso seat belts reduces the probability of fatality by 55% and that of injury by 42% on average.

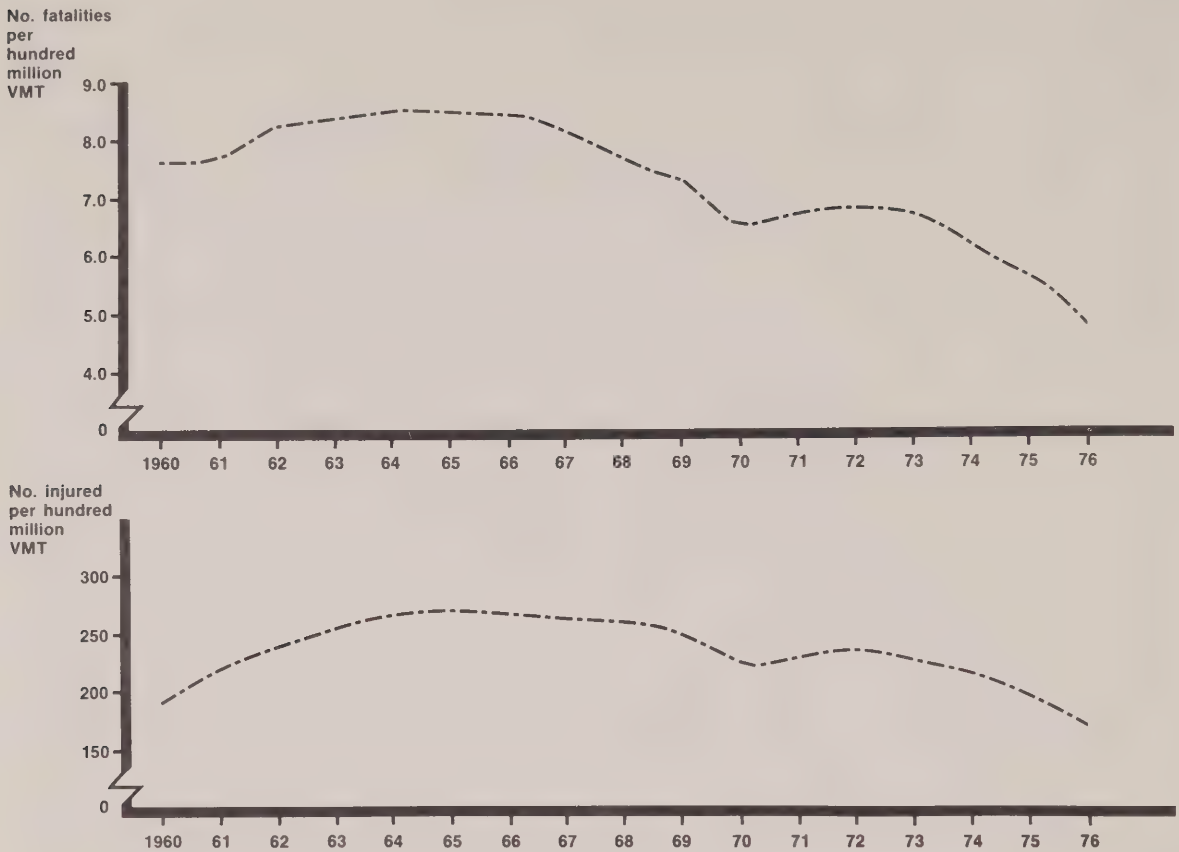
In 1974, a national survey estimated that lap-torso belts were worn by drivers in 15% of vehicle miles, and lap belts alone in a further 5%. Assuming the position was the same in 1975, the protection offered by these levels of belt use is included in the accident statistics for 1975, and consequently in the "base" forecasts made using 1975 accident and casualty rates. However, at the beginning of 1976, the wearing of seat belts became compulsory in Ontario; essentially of lap-torso belts in vehicles with integral lap-torso systems, and of lap belts otherwise. Similar provisions were also enacted in Québec, effective in mid-1976. Experience in other jurisdictions with compulsory seat belt use laws suggests that wearing rates of 80% or more are sustainable. While this is somewhat higher than appears currently to be the case in Québec and Ontario, there is evidence that newer, more convenient belt systems are used more frequently, that younger occupants use belts more frequently, and that belt use becomes habitual over time. It does not, therefore, seem unreasonable to expect that belt use might achieve 80% where compulsory by 1985 (by which time almost the entire fleet will be equipped with integral lap-torso belt systems). Using the above estimates of seat belt effectiveness, it can then be predicted that 80% belt use in Québec and Ontario in 1985 would reduce car occupant fatalities by 20% and car occupants injured by 17.6% over the initial (1975 rates) forecasts.

Seat belt use became compulsory also in Saskatchewan and British Columbia during 1977, and there are indications that other provinces will follow suit. Assuming that such laws were enforced throughout the entire country, achieving 80% use by 1985, reductions of 37% in car occupant fatalities and 27.5% in car occupants injured would be achieved, relative to the initial forecasts.

Impacts of Reduced Speed Limits

Recent experience in the United States and Europe supports research predictions that reduced highway speed limits might significantly reduce accidents and reduce the average severity of remaining accidents. The recent empirical results have been confounded to some extent by reductions in traffic, and shifts in the distribution of trip purposes, driver ages, and other travel variables important to accident experience; and also by the incentives to compliance with speed limits provided by apparent shortages of gasoline. However, United States analyses suggest that reduction of highway speeds alone can result in fatality reductions of 10 - 20% overall.

Figure 6.4 Casualty Rates 1960-1976



Source: Road and Motor Vehicle Traffic Safety, Transport Canada.

Reductions of highway speed limits similar to those in the United States were introduced in British Columbia in late 1974. Preliminary evidence has suggested that this resulted in a reduction of fatalities on the relevant road network by about 20%. Speed limits were subsequently reduced in Ontario in 1976 (to 60 m.p.h. on limited-access highways and 50 m.p.h. generally on all-purpose highways). Applying United States experience to these three provinces, reduced somewhat to allow for the smaller average speed limit changes, and to allow for problems of enforcement, suggests that overall reductions in these provinces of 5% in total accidents might be achieved; but that severities of resulting injuries would be reduced such that fatalities fell by 10% while injured fell by only 5%. Such reductions would amount in 1977 to reductions in total Canadian accidents and injured casualties of 3.6%, and in total Canadian fatalities of 7.2%.

If the speed reductions were subsequently achieved in all jurisdictions, the full reductions of 5% in accidents and injured casualties and 10% in fatalities could be achieved.

Federal Government Programmes

The major direct federal government impact on accident and casualty rates will continue to be through vehicle performance standards under the Motor Vehicle Safety Act. It seems likely that much of the possible general improvement in passenger car performance through standards has been achieved, since initial United States regulations in the late 60's and Canadian regulation since 1970. Major future improvements are difficult to identify, based on current knowledge of technological possibilities and predictions of their cost-effectiveness. Attempts will be made below to:

- predict the continuing impacts of standards implemented to 1975;
- predict the impacts of standards expected to be implemented to 1980;
- identify and predict the impacts of some major standards options from 1980 to 1985, for which the hardware solutions are relatively foreseeable; and
- identify some broad fields for standards beyond 1985, in which considerable technological development is necessary before any predictions of effectiveness can be made.

Continuing Impacts of Standards to 1975

The base forecasts using 1975 accident and casualty rates will include the impacts of safety standards mandated to 1975; but some allowance must be made for the continuing impacts of these earlier standards, as more of the full fleet becomes equipped to meet them. The effectiveness of these standards has proven difficult to identify precisely from analyses of accident statistics over the relevant periods, because the contributions of vehicle features to accident occurrence and severity are only partly assessed in police investigations, and also because a number of other influences confound the trends in the statistics. It can be concluded with

relative certainty, however, that occupant protection improved significantly over the model years 1966 to 1975. To allow a significant continuing impact as sub-standard vehicles are replaced at a reasonable rate, it will be assumed that the initial forecasts of casualties will be reduced by a proportion growing to 3% in 1985 and remaining constant thereafter.

Passenger Car Safety Standards to 1980

Unique Canadian standards are proposed to improve control locations and symbols, to improve direct visibility (through defogging and defrosting systems, etc.) and to improve signalling systems. In addition, standards are proposed in both Canada and the United States to promote crash avoidance by improved brake system performance and upgrading lighting; and to promote crash protection by improved seating systems and head restraints, limiting windshield zone intrusion, and upgrading fuel system crash integrity.

No precise estimates are available of the likely accident and casualty reductions resulting from these proposed standards. In general, they are modifications to existing standards; to reduce stopping distances of some cars, for example, or to improve the seating systems and head restraint standards by promoting integral head restraints in stronger seats. The solutions to such standards are available, and in fact exist in parts of the car population at present, and have the potential to be implemented at little extra cost (or perhaps even with cost savings, in some instances). Their contribution to safety could be significant, but it is unlikely that the accidents and casualties at which they are addressed form a large proportion of the totals. The true effectiveness of these measures must be the subject of research in the immediate future. In the interim it will be assumed, for purposes of illustrating the likely subsequent impacts of a few major options beyond 1980, that standards implemented 1975-1980 will be of a general order of effectiveness similar to that assumed above for standards after 1970: that they would reduce fatalities and injuries by 1 or 2%.

Standards Options 1980-1985

An attempt can be made to predict feasible improvements to vehicle performance which could be implemented through vehicle performance standards beyond 1980. Prediction of the hardware solutions to such standards, their likely costs, technical efficiencies, and any weight penalties is necessarily hazardous. To demonstrate the likely order of magnitude of the impacts of standards imposed between 1980 and 1985, a group of measures has been identified which could prove cost-effective. The group would include the following aspects of vehicle performance:

- improved visibility of rear signal displays;
- improved forward night visibility;
- reduced stopping distances under wet road conditions;
- systems to prevent vehicle operation by intoxicated drivers; and
- extended lateral intrusion protection (to 30-35 km/h - 4,000 lb. moving barrier impact).

The combined impacts of the appropriate standards, met simultaneously, are estimated to reduce casualties over the base forecasts by approximately 7% by 1990.

Air Cushion Restraint Systems (ACRS) vs. "Active" Seatbelts

The omission of "passive" occupant restraint systems from the above list of possible performance standards for 1980 to 1985 deserves some explanation, in the light of the recent United States government decision to require passive restraints in cars from the early 1980's. The simple explanation, which will be expanded below, is the assumption that existing "active" restraint systems – the available seat belts – will come to be used sufficiently extensively that passive systems (i.e., those not requiring user action in order to be effective), which are more complex and expensive, would be unnecessary.

The discussion focusses on the relative technical effectiveness of the alternative systems, their predicted use rates, and their relative costs. The major alternatives considered are the active lap-torso seat belt system, the air cushion restraint system (ACRS), a combination of ACRS with active lap belt, and the passive torso belt and knee bolster system. Recent United States government estimates of the effectiveness of these systems are presented in the following Table 6.1.

These estimates for passive restraint systems must be viewed with considerable caution, as they are based on very limited real-world data (while the effectiveness of active belt systems has been relatively well demonstrated). However, the current estimates would suggest that active lap and torso seat belt systems are inherently more effective in reducing injury than are the passive alternatives. Further, the most promoted passive system, the ACRS, would only approach an equivalent effectiveness to the active system when supplemented by an *active* lap belt system (and, on the basis of these estimates, would remain *even then considerably less* effective in avoiding lower-severity injuries).

Table 6.1 Rates of Effectiveness of Restraint Systems in Reducing Car Occupant Casualties, Abbreviated Injury Scale (AIS) Level

AIS* Level	Active Lap-Torso Seat Belts	ACRS**	ACRS Plus Active Lap Belt	Passive Torso Belt and Knee Bolster
1	0.30	0.00	0.15	0.20
2	0.57	0.22	0.33	0.40
3	0.59	0.30	0.45	0.45
4 - 6	0.60	0.40	0.60	0.50

* The Abbreviated Injury Scale classifies injuries by severity in a comprehensive manner, a brief description of which is as follows:

AIS Level	*Description of Injury*
1	*Minor (e.g., simple sprain)*
2	*Moderate (e.g., simple fracture)*
3	*Severe (e.g., severe fracture or dislocation of major joint)*
4	*Serious Non-Fatal (e.g., amputated limbs, survival expected)*
5	*Critical Non-Fatal (e.g., critical organ injuries, survival uncertain)*
6	*Fatal*

** Air Cushion Restraint System

Source: United States Federal Register, v. 41 no. 148, July 30, 1976, pp. 31861-63.

Therefore, on the basis of these estimates, if 100% use of active systems could be guaranteed, passive systems would be ruled out as less effective, as well as more expensive, even if supported by an active belt system. More practically, it can be deduced that active seat belts remain more effective than the passive systems at lower use rates. As an example, if it is assumed (as it has been in the more optimistic of the United States estimates) that active lap belt use would reach 25% with an ACRS, then interpolation from the estimates in the table above would suggest that lap-torso belt use rates would be as effective as the passive system: down to rates of about 55% for AIS Level 3, 45% for AIS Level 2, and less than 25% for AIS Level 1.

The considerable costs of passive systems must also be brought into the comparison: estimates of the incremental cost of the ACRS plus lap belts over active lap-torso belts range between about $80 and $330 per vehicle (1976 prices), amounting therefore to an annual increment of $80-$330 million at current sales levels. On a cost-effectiveness basis, active belts would then be favoured at use rates still lower than those required to achieve equal absolute effectiveness to passive systems.

The tentative conclusion, therefore, is that achievement of the 80% active seat belt use which is currently considered feasible (and assumed in the forecasts below) will be more effective than passive restraint alternatives. However, the issue does remain open, awaiting practical developments in active belt use and firmer evidence of the effectiveness of passive restraints.

Options for Implementation Beyond 1985

Current technology does not allow the identification of specific cost-effective safety standards beyond 1985. A number of possible targets for standards-making can be suggested, but considerable development would be required in all cases. The most promising suggested targets are as follows:

- maintenance-free braking capability;
- automatic hazards-warning, or hazards avoidance;
- increased occupant protection (to 80km/h);
- pedestrian impact protection; and
- vehicle damage protection to 16km/h front and rear.

Research into the effectiveness of proposals in these fields will continue.

Forecasts of Casualties

As noted in Passenger Car Safety Standards to 1980, accidents and casualties are forecast to vary directly with VMT, modified only by the impacts of the countermeasures foreseen in Standard Options 1980-1985. The AMT estimates, by scenario, are presented in Table 6.2.

A base forecast is first made for each scenario, with accident and casualty rates constant at their 1975 levels, modified slightly to include an estimate of the continuing impact of vehicle safety standards mandated to 1975, as these work through the full fleet. These forecasts are not realistic, but serve to demonstrate the impacts of major countermeasures considered subsequently. The forecasts are presented as "A" in Table 6.3. With a fatality rate of approximately 5.6 per 100 million vehicle miles, fatalities under the normal scenario would double from 6,061 to about 12,300 in 2000, while the extremes of low growth and high growth would see fatalities grow by 34% and 140% respectively. The numbers of injured, with a rate of 2.04 per million VMT, would be forecast to grow at the same rates.

Table 6.2 Forecasts of AMT by Scenario (passenger car AMT, billions)

Year	Scenario		
	Low	Normal	High
1975	87	87	87
1985	92	115	120
2000	113	172	210

Note: These are forecasts of passenger car AMT, while the casualty rates used relate to *total* VMT. This is estimated in 1975 at 108 billion; and non-car VMT is assumed to grow subsequently at the same rate as car AMT.

The second set of forecasts, "B" in Table 6.3, includes estimates of the impacts of compulsory seat belt wearing and reduced speed limits in those provinces where they existed in early 1977, as predicted in "Standard Options 1980-85" above. These measures provide reductions in the overall fatality rate of about 18%, to 4.6 per 100 million vehicle miles and in the total injured rate of about 16%, to 1.72 per million vehicle miles over the entire forecast period.

The final set of forecasts, "C" in Table 6.3, includes current best estimates of 80% seat belt use and reduced speed limits throughout the country, producing reductions in the fatality rate of about 29% and in the injury rate of about 23% from the base forecasts; and includes also the "Package" of safety standards to 1985, which provides an additional impact ultimately (once worked through the full fleet) of about 7% in the fatality rate and about 8% reduction in the injury rate. The ultimate rates become 3.7 per 100 million VMT for fatalities and 1.43 per million VMT for injured; producing under the normal Scenario an increase in fatalities of some 35% between 1975 and 2000, and an increase in injured of about 43% over the period. Under the high growth Scenario fatalities would rise by about 60% and injured by about 70% over that period; while with low growth both fatalities and injured would actually fall (by about 10% and 4%, respectively).

To forecast a "most likely" set of casualty rates, it seems reasonable initially to assume that the "B" forecasts will at least be achieved, requiring only the success of seat belt use laws and reduced speed limits in those provinces where they

Table 6.3 Forecasts of Fatalities and Injured

Basis of Forecast		Scenario		
		Low	Normal	High
A.Trend at 1975 Rates				
Fatalities	1975	6,061	6,061	6,061
	1985	6,404	8,079	8,434
	2000	8,207	12,316	14,778
Injured	1975	220,498	220,498	220,498
	1985	232,578	293,438	306,332
	2000	298,067	447,303	536,723
B.1977 Seat Belt Use and Reduced Speeds				
Fatalities	1975	6,061	6,061	6,061
	1985	5,280	6,661	6,954
	2000	6,766	10,154	12,184
Injured	1975	220,498	220,498	220,498
	1985	196,496	247,913	258,807
	2000	251,824	377,907	453,455
C.80% Seat Belt Use and Reduced Speeds				
Fatalities	1975	6,061	6,061	6,061
	1985	4,544	5,667	6,082
	1990	4,645	6,294	6,996
	2000	5,443	8,186	9,800
Injured	1975	220,498	220,498	220,498
	1985	176,212	219,617	235,595
	1990	178,862	242,357	269,375
	2000	209,563	314,488	377,357

existed in early 1977. The "C" forecasts are also achievable, requiring the extension of such measures throughout the country (which seems likely), and the success of extended vehicle performance standards. What is more in doubt is whether further reductions in the rates can be achieved, from additional countermeasures not foreseen in the forecasts. As was noted, such measures would be provincial or municipal programmes controlling road user behaviour or vehicles in use, but practical and cost-effective programmes are currently difficult to identify. It does, however, seem reasonable to speculate that both the pressures to develop innovative measures and the availability of resources to implement them would be greater under the high growth scenarios. Therefore, while the measures foreseen in the forecasts do not vary by scenario, it is possible that the achieved rates would be lower under the normal and high growth scenarios.

Sensitivity of Forecasts to Some Major Assumptions

The major assumption made in the above forecasts which is subject to question is that casualty rates per VMT would remain *constant* in the absence of major safety programmes. As was noted above, this assumption ignores the possibility that changes in VMT will be accompanied by shifts in the distribution of VMT by some variables with significantly different accident and casualty rates. A lengthy list of variables important in determining the accident and casualty rates, and which might be expected to vary over time, could be identified. Major among these would be: driver descriptors such as age, sex, condition (e.g., alcohol use); road types (or urban/rural); time of day, week and year; trip purpose; and vehicle type (e.g., size or weight, age and condition). Unfortunately, no detailed data exist on the distributions of VMT over time by these variables from which their independent influences might be distinguished.

However, the VMT estimates and forecasts for the Role of the Automobile Study do make distinctions among some of these variables or proxies for them, and attempts can be made to indicate their possible impacts by hypothesizing their influence on accident and casualty rates. Specifically, attempts will be made below to consider the possible importance of shifts in the size distribution of the car fleet; of shift in the distribution of VMT by community size; and of shifts in the distribution of VMT by trip purpose.

Impacts of Shifts in the Car Fleet Size Distribution

There is some considerable concern that smaller, lighter vehicles have higher accident and casualty rates than their larger counterparts. This is to some extent borne out by research, though there is no definitive study which distinguishes the contribution of the vehicles themselves from the nature of their users and the manner of their use. Nor can there be any automatic presumption that the situation will remain the same as technology advances and vehicle occupant protection improves through restraint use.

The current size distribution of the fleet was estimated in the study (ref. 17) as were the market shares of vehicles of different sizes in the years 1985 and 2000. These forecast shares vary by Scenario, achieving maximum shifts to smaller vehicles in the low growth Scenario in 1985, and the normal growth Scenario in 2000, which can be used therefore to represent somewhat extreme situations. The fleet distributions by size associated with these market shares are not explicitly forecast in the Study, but can be reasonably inferred as in Table 6.4.

Then if the relative casualty rates associated with vehicles of different sizes can be hypothesized, the impacts of the above shifts in the size distribution can be calculated simply. Two alternative hypotheses of relative rates will be examined, the former seeming more reasonable than the latter.

Table 6.5 Relative Casualty Rates

Vehicle Size Class	Hypothesis 1	Hypothesis 2
Small	1.20	1.50
Compact	1.15	1.25
Full Size	1.05	1.05
Large	1.00	1.00

It can then be shown that a shift from the 1975 fleet size distribution to that estimated for 1985 (low growth) would produce overall increased casualty rates of 3.1% under hypothesis 1 and 6.0% under hypothesis 2, while the shift estimated between 1975 and 2000 for normal growth would produce increased casualty rates of 4.8% under hypothesis 1 and 9.7% under hypothesis 2. These possible increases might be off-set, however, by the lower probabilities of collisions between smaller vehicles and fixed objects, and the lesser impacts of smaller vehicles on more vulnerable road users such as pedestrians, cyclists and motorcyclists.

Impacts of Shifts in Urban/Rural Distribution of Travel

Accident and casualty rates differ significantly between urban and rural travel; and the distribution of VMT by community size is forecast in the Role of the Automobile Study to change significantly over time (toward more urban travel). The precise causes of the different accident and casualty rates are likely complex, involving the influences of differing operating speeds, road characteristics and perhaps the time distribution of travel, among other factors. However, if it can be assumed

Table 6.4 Distribution of Vehicle Size Classes for Low Growth (1985) and Normal Growth (2000) Scenarios

Vehicle Size Class	1975 Fleet	1985 Market Shares Low Growth	1985 Fleet Distribution* Low Growth	2000 Market Shares Normal Growth	2000 Fleet Distribution* Normal Growth
Small	.19	.35	.30	.40	.35
Compact	.23	.35	.30	.40	.35
Full Size	.39	.20	.20	.10	.15
Large	.19	.20	.20	.10	.15

* Inferred from market shares, and trend.

that the influences of these factors remain constant over time, such that the relationship between urban and rural casualty rates remains constant, some broad implications of the shift toward urban travel can be assessed.

The forecasts made in the Study include estimates of auto travel generated by communities of different sizes (ref. 17), distinguishing "Census Metropolitan Areas" from "Urban areas 25,000 - 100,000", and from "small urban and rural" communities. The forecast distributions hardly vary by scenario, but change significantly over time. The 1975 base distribution and distributions for the normal growth scenario in 1985 and 2000 are as follows:

Table 6.6 Proportions of VMT Generated by Community Size

Community Size	1975 Base %	1985 %	2000 %
CMA's	53.7	59.4	62.9
Urban Areas 25-100K	9.6	9.3	9.1
Small Urban & Rural	36.7	31.3	28.0

This categorization of traffic generated by different community sizes does not match the distribution of traffic or the accident statistics, so precise accident and casualty rates for these categories cannot be calculated. However, taking a 60/40 urban/rural traffic distribution (see Table 1.3) in 1975, and assuming that "small urban and rural" will be representative of the rural trend, the urban/rural split would be 66/34 in 1985 and 70/30 in the year 2000. Then assuming that total travel in 1975 (108 billion VMT) was distributed accordingly with the figures, fatality and injury rates for urban and rural areas can be estimated from the accident statistics. The estimates appear in Table 6.7.

Now the average fatality and injury rates (on a 1975 accident rate basis) can be calculated for the differing proportions of urban vs. rural VMT forecast in the Study. Results of the calculation are shown in Table 6.8.

The calculations show that with fatality rates differing so greatly between urban and rural travel (the rural rate being $3^1/_2$ times the urban), the overall fatality rate might fall significantly as the proportion of urban travel rises over time. The above figures show (other things being equal) a reduction in the fatality rate of 7.6% between 1975 and 1985, and of 12.3% between 1975 and 2000.

The rates of injury estimated above for urban and rural travel are, however, so similar that virtually no change would be predicted in the overall injury rate with a shift in the proportion of urban travel of the magnitude forecast in the Study.

Impacts of Shifts in the Distribution of Traffic by Trip Purpose

The possible influences of shifts in VMT by trip purpose should be examined, as the Study makes forecasts of VMT by trip purpose, and as it might be supposed that different trip purposes would be associated with different rates of accidents and casualties. However, a brief examination shows that the differences in this distribution of VMT over time or among scenarios are so slight as to be insignificant in the rough estimation procedure followed above. Indications of some of these differences are presented in Table 6.9.

The Costs of Road Accidents

There are considerable philosophical and practical difficulties and objections to estimating the costs of highway accidents, but since insurance premiums (at about $1.25 billion in 1975) only cover a portion of the cost of accidents, it seems preferable to value them as fully as possible, in order to give them as high a weight as possible (ref. 36). In this connection, it may be noted that, mainly because of their heavy incidence on younger male adults, road accidents were classified as the biggest single cause of death in the sense of years of life foregone from ages 1 - 70 in 1974 (ref. 5).

There are many consequences of road accidents which are impossible to value such as the pain and mental anguish of victims and others, and there are many minor consequences such as police and legal costs on which it is difficult to obtain data. However, concentrating on the major measurable consequences and costs, these consist of three major elements, property damage, loss of earnings and/or work efforts (including housewives at current wage rates) and health care, and these have been estimated (ref. 36) as at least the figures in Table 6.10.

This Table shows that the largest elements of accident costs are property damage (mainly to vehicles in many fatal, injury and damage only accidents) and lost work efforts. Including health care, the cost of accidents in 1975 accounted for at least $2.5 billion, or about 15% of the total expenditures on road vehicle operation (see Chapter 1), and about twice the level of insurance premiums which totalled some $1.25 billion in 1975. This Table also shows that fatal accidents and victims (at $150,000 per fatal accident and $120,000 per fatality) were by far the most costly, accounting for about 40% of total accident cost. This suggests that even though fatal accidents and accident rates have been falling, and are expected to fall even further, that even more attention should be paid to them, and to cost-effective measures to reduce them even further, with special emphasis on measures to further reduce the higher fatality rates in rural areas (see Table 6.6) for example, via lower speeds, seat belts, etc., and other measures in the above lists.

Table 6.7 Casualty Rates by Urban/Rural Traffic 1975

Community Size Class	Proportions AMT 1975	VMT (Billions)	Estimated Deaths 1975	Fatality Rates*	Estimated Injured 1975	Injury Rates*
Urban	60	.65	1,841	2.8	136,532	210
Rural	40	.43	4,234	9.8	84,393	196

* rates per 100 million vehicle miles.

Table 6.9 Proportions of VMT Accounted for by some Representative Trip Purposes

Trip Purpose	1975	1985 by Scenario			2000 by Scenario		
		Low	Normal	High	Low	Normal	High
Commuting	37.5	37.3	37.6	37.6	37.3	38.0	38.1
Commercial	9.8	10.0	9.8	9.8	10.1	9.5	9.4
Recreation	16.1	16.5	16.4	16.4	16.5	16.2	16.1
Weekend	8.7	8.7	9.2	9.2	10.0	9.9	10.1

Table 6.8 Average Casualty Rates with Changing Proportions, Urban vs. Rural VMT

	1975	1985	2000
Proportion Urban VMT	.60	.66	.70
Proportion Rural VMT	.40	.34	.30
Average Fatality rate*	5.60	5.18	4.90
Average Injury rate*	204.00	203.00	203.00

* rates per 100 million vehicle miles

Table 6.10 Estimated Accident Costs 1975

Totals ($ billions)	
Property Damage	$1.4
Lost Work Efforts	1.0
Health Care	0.1
	$2.5
Average Accident Costs	
Fatal Accident	$150,000
Injury Accident	6,000
Property Damage Accident Only	800
Average Victim Costs	
Fatality	$120,000
Injured Victim	2,000
Average Victim	5,000

Sources: Road Safety Branch, Transport Canada, "Technical Memoranda on Values of Safety, Costs of Damage to Vehicles and other Property in Road Accidents, and Value of Work Efforts Lost as a Result of Road Accidents" 1976.

Environmental Implications of the Automobile

Air Quality

The major sources of air pollution from the automobile are carbon monoxide (CO) which interferes with the transport of oxygen in the blood supply (with other adverse physical effects), hydrocarbons (HC) and nitrogen oxides (NOx) which have adverse but unknown effects on lung tissue. The latter two also interact in the presence of sunlight to produce ozone*, and smog, particularly in the period June to September. It has been estimated that in 1972 the motor vehicle was responsible for almost 60% of total urban air pollution, with 60% of carbon monoxide, 50% of hydrocarbons and 50% of nitrogen oxides, totalling nearly 12 million tons, of which 82% was carbon monoxide (ref. 35).

The present Canadian standards (1975-85) for new automobile emissions are 2.0 grams per mile (gpm) of hydrocarbons, 25 gpm of carbon monoxide, and 3.1 gpm of nitrogen oxides. Together these standards for new cars (as compared with uncontrolled vehicles) are estimated to have resulted in a reduction of about 75% for hydrocarbons and carbon monoxide, and about 11% for nitrogen oxides, at some past extra costs in terms of auto costs and prices and increased fuel consumption.

The future trend of air pollution from the automobile will be determined by the growth of urban automobile miles travelled, and the future emission standards to be adopted as they work their way through the automobile fleet, plus any deterioration of vehicles in use. Using the CMA auto mileage forecasts from Chapter 3, and using as examples 1975-80 standards, and standards improved toward United States standards of 0.9 gpm HC, 9gpm CO, and 2 gpm NOx, the future trends of auto air pollution can be estimated as in Table 6.11. 1975 AMT and 1975 outputs of pollutants are expressed as 100 and the results presented as indices in these terms. These tentative and inevitably controversial estimates suggest that although present (1975-80) emission standards are adequate to reduce auto air pollution from all sources below 1975 levels up to 1985-90 for all scenarios, by the year 2000 present standards and increased urban AMT may result in outputs of nitrogen oxides in excess of 1975 levels for the normal and high growth scenarios.

Improved standards for NOx may be called for by end-century for normal and high growth situations therefore, at some additional costs in terms of auto prices and fuel consumption. In this connection it should be noted that there are complex benefits and costs involved in disassociating with more stringent United States standards, which are scheduled to move to HC 0.4 gpm, CO 7 gpm and NOx 1 - 2 gpm by 1981. Therefore, the longer term Canadian outlook after 1985 can only be determined by complex policy decisions, as the future unfolds in terms of urban auto mileage and pollution, and energy consumption.

Noise and the Automobile

The effect of noise from the automobile on the external environment from engines, tires and wind resistance can be regarded as mainly determined by the noise of the traffic flow (of which the automobile is a part), its effect on those involuntarily exposed to it, and the number of persons involuntarily exposed to traffic noise. To define and measure the generation of traffic noise, it should be pointed out that the most conventional method (with several variants) is via decibels on the A scale (dBA). This is an overall measure of all the components of sound, with special weighting for the way the

*Condensed form of oxygen with 3 atoms to the molecule instead of normal 2, generated also by sources other than the automobile.

Table 6.11 Estimated Effects of Alternative Emission Standards on Auto Air Pollution 1985 and 2000

Date, Urban AMT and Pollutant	Scenarios and Index (1975 = 100) Low Growth	Normal Growth	High Growth
1985			
Urban Auto Miles Travelled	120	150	160
1975-80 Standards	(HC 2 gpm,	CO 25 gpm,	NOx 3.1 gpm)
HC	42	53	57
CO	36	45	48
NOx	62	77	82
Improved Standards	(HC 0.9 gpm,	CO 9 gpm,	NOx 2 gpm)
HC	26	32	34
CO	24	30	32
NOx	50	63	67
2000			
Urban Auto Miles Travelled	153	232	282
1975-80 Standards			
HC	53	82	100
CO	46	70	85
NOx	79	119	145
Improved Standards			
HC	15	22	27
CO	14	21	26
NOx	63	94	115

Sources: Working Paper No. 18.

human ear responds to sounds of different frequencies, and with good correlation with people's annoyance and judgement of loudness. Since decibels are measured on a logarithmic scale, an increase of 10 dBA roughly doubles the apparent loudness, and some indications of the effect of different levels of noise are given in Figure 6.5 (ref. 37). In general, a sound level in excess of 55 dBA is unacceptable without good sound insulation to dwellings, and levels above 75 dBA are regarded as unacceptable. The data in Figure 6.5 and Tables 6.12 and 6.13 which show the noise levels at 100 ft. distance from highway centre lines for speed limits of 30 m.p.h. (urban) and 60 m.p.h. (rural) have been interpreted in this way. Special attention must be given to the noisier vehicles however, such as trucks, buses and motorcycles, which are similar in their noise levels.

In general, the sound levels given in these tables show that noise levels increase comparatively little with traffic volumes, a ten-fold increase in traffic volume being required to produce a doubling in apparent noise levels, with a probable trend toward slightly greater noise levels with smaller automobiles. Normal remedies such as lower speed limits, sound barriers, and greater distances from highways have a correspondingly small effect (ref. 34). It seems, therefore, that traffic noise will increase comparatively little with future traffic volumes (at an annual rate of 0.1 to 0.4 dBA), and is correspondingly difficult to reduce, except by the regulation of the noisier vehicles — trucks, buses and motorcycles.

Concerning the incidence of traffic noise, it has been estimated that some 200,000 persons (1% of the population) are exposed to traffic noise levels in excess of 75 dBA, and that about 6,000,000 persons (26% of the population) are exposed to noise levels in excess of 55 dBA (ref. 35). Without adequate sound insulation of dwellings (or control of noisier vehicles) these proportions would probably grow slightly in the future. To estimate urban and rural incidences, since about 60% of traffic and 80% of the population are urban (see Chapter 1), it can be expected that most of the incidence will be urban, particularly near urban expressways with high speed limits, and that most of the growth of the environmental incidence of traffic noise will probably be urban.

Other Environmental Matters

Lead

Lead additives are presently the most convenient and economical method of increasing the octane number (measurement of the anti-knock properties) of all gasolines, in particular, those required for use in engines with high compression ratios. A lead content of 3.1 grams per Imperial gallon (2.6 per United States gallon, 0.7 grams per litre) of gasoline will raise the octane rating by six to eight numbers, making it possible to refine 92-94 octane fuel to the 100-plus octane grades required by these engines (ref. 35).

In 1970, automobile emissions accounted for 65% (14,000 tons) of the total airborne emissions of lead in Ontario. Under the Clean Air Act, the lead content of gasoline has been restricted to a maximum of 3.5g per Imperial gallon, effective January 1, 1976. The lead content of Canadian gasoline in 1972 ranged from 0 - 0.54g per litre (0 - 2.45g per Imperial gallon) for regular, and 0.67 - 0.70g per litre (3.04 - 3.18g per Imperial gallon) for premium (ref. 35). Approximately one-quarter of the lead added to gasoline is retained in the exhaust system, engine oil and filters of the automobile. The rest is discharged in the form of particulate lead compounds, about half of which falls to the ground within a short distance of the roadway. The remainder is carried by wind.

Although present levels of lead in the ambient air are not considered to be a danger to public health, in measureable quantities lead definitely causes severe nervous disorders, including paralysis and loss of perceptive and mental acuity. Concern about the total amount of lead entering the environment and about undetected and indetectable negative effects prompted the "ceiling" on lead content in gasoline discussed above. It is expected in any case that the introduction of engines with low octane requirements and /or catalytic emission control systems will ensure that unleaded fuels will dominate the Canadian market before 1985.

Salt

Salt is presently used on an extensive scale in certain parts of Canada to melt ice and snow from 0°C (32°F) down to temperatures of -18°C (0°F) in order to secure efficient and safe winter driving in this temperature range. The use of salt on highways (at about 2.5 million tons in 1975) has been increasing rapidly in recent years, and since it has adverse effects on the environment and corrosive effects on automobiles, some levelling off in its use might be considered (ref. 35).

Land Use and Consumption by the Automobile and Urbanization

Quantitatively, the consumption of land by the automobile and the highway system (at up to about 10,000 sq. miles or 0.3% of Canada's land area) is negligible, but is much more significant and visible qualitatively particularly in urban areas. A study of direct plus indirect land absorption by the highway system, parking, etc., in urban areas (ref. 1) has shown that it absorbed about 20% (1 sq. mile) of a typical small city of 19 sq. miles and 120,000 population, down to 16% (25 sq. miles) of a metro area of 1.5 million population. In the latter case, some 42% of the central area was devoted to highways directly and

Figure 6.5 Common Noise Levels and Typical Reaction

Sound Source	Noise Level (dB)	Apparent Loudness	Typical Reaction	CMHC Requirements: Categories	CMHC Requirements: dB	CMHC Requirements: Maximum Acceptable Levels
	135		Painfully loud Limit amplified speech			
Military Jet	130	Sixty-four times as loud				
Jet takeoff at 200′	120	Thirty-two times as loud				
	110	Sixteen times as loud	Maximum vocal effort	Unacceptable		
Jet takeoff at 2,000′	100	Eight times as loud				
Freight Train at 50′	95					
Heavy truck at 50′ Busy city street	90	Four times as loud	Very annoying Hearing damage (8 hours)			
	80	Twice as loud	Annoying			
					75	
Highway traffic at 50′	70	Base reference	Telephone use difficult	Unacceptable without adequate sound insulation		
Light car traffic at 50′	60	Half as loud	Intrusive			
					55	Outdoor Recreation
Noisy office	50	Quarter as loud	Speech interference	Normally acceptable	45	
					45	Kitchens Bathrooms
Public Library	40	Eight as loud	Quiet		40	Living/ Dining
					35	Bedrooms
Soft whisper at 15′	30	Sixteenth as loud	Very quiet			
	10	Sixty-fourth as loud	Just audible	Acceptable		
Threshold of hearing	0					

Note: The minimum difference in noise level that is noticeable to the human listener is 3 dB. A 10 dB increase in level appears to double the loudness while a 10 dB decrease halves the apparent loudness.

Source: Road and Rail Noise Effects on Housing, CMHC, 1977.

indirectly, making them highly visible to many people, with adverse visual and environmental impacts.

In a somewhat similar situation, the absorption of land by urbanization at about 3 dwellings per gross acre (or 2.25 million acres, 3,500 sq. miles or 0.1% of Canada's land area) was negligible in 1975, but highly visible to many people and tending to absorb better quality farmland in warmer climates (ref. 34). Urban growth is also a matter of considerable concern, and likely to absorb up to a further 2,340 sq. miles by end-century (0.07% of Canada's land area) (ref. 7 and 17), the major effects again being qualitative, visual and environmental rather than quantitative.

Table 6.12 Equivalent Noise Level at 100 ft. from Centre Line if Posted Speed Limit is 30 m.p.h.

Daily volume (vehicles per 24 hr)	Percentage of trucks up to 1.0	1.1 to 3.0	3.1 to 5.0	5.1 to 7.5	7.6 to 10	11 to 13	14 to 18	19 to 23	24 to 29	30 to 39	40 to 52	53 to 69	70 to 89	90 or over
960	49	50	51	52	53	54	55	56	57	58	59	60	61	62
1200	50	51	52	53	54	55	56	57	58	59	60	61	62	63
1500	51	52	53	54	55	56	57	58	59	60	61	62	63	64
1900	52	53	54	55	56	57	58	59	60	61	62	63	64	65
2400	53	54	55	56	57	58	59	60	61	62	63	64	65	66
3000	54	55	56	57	58	59	60	61	62	63	64	65	66	67
3800	55	56	57	58	59	60	61	62	63	64	65	66	67	68
4800	56	57	58	59	60	61	62	63	64	65	66	67	68	69
6000	57	58	59	60	61	62	63	64	65	66	67	68	69	70
7440	58	59	60	61	62	63	64	65	66	67	68	69	70	71
9600	59	60	61	62	63	64	65	66	67	68	69	70	71	72
12000	60	61	62	63	64	65	66	67	68	69	70	71	72	73
15000	61	62	63	64	65	66	67	68	69	70	71	72	73	74
19000	62	63	64	65	66	67	68	69	70	71	72	73	74	75
24000	63	64	65	66	67	68	69	70	71	72	73	74	75	76
30000	64	65	66	67	68	69	70	71	72	73	74	75	76	77
36000	65	66	67	68	69	70	71	72	73	74	75	76	77	78
48000	66	67	68	69	70	71	72	73	74	75	76	77	78	79
60000	67	68	69	70	71	72	73	74	75	76	77	78	79	80
74000	68	69	70	71	72	73	74	75	76	77	78	79	80	81
96000	69	70	71	72	73	74	75	76	77	78	79	80	81	82
120000	70	71	72	73	74	75	76	77	78	79	80	81	82	83
150000	71	72	73	74	75	76	77	78	79	80	81	82	83	84
192000	72	73	74	75	76	77	78	79	80	81	82	83	84	85
240000	73	74	75	76	77	78	79	80	81	82	83	84	85	86

Note: Values in body of this table are A-weighted noise levels expressed in dB. *Source: Road and Rail Noise Effects on Housing, CMHC, 1977.*

Table 6.13 Equivalent Noise Level at 100 ft. from Centre Line if Posted Speed Limit is 60 m.p.h.

Daily volume (vehicles per 24 hr)	Percentage of trucks up to 1.0	1.1 to 3.0	3.1 to 5.0	5.1 to 7.5	7.6 to 10	11 to 13	14 to 18	19 to 23	24 to 29	30 to 39	40 to 52	53 to 69	70 to 89	90 or over
960	55	55	56	56	57	57	58	59	59	60	61	62	63	64
1200	56	56	57	57	58	58	59	60	60	61	62	63	64	65
1500	57	57	58	58	59	59	60	61	61	62	63	64	65	66
1900	58	58	59	59	60	60	61	62	62	63	64	65	66	67
2400	59	59	60	60	61	61	62	63	63	64	65	66	67	68
3000	60	60	61	61	62	62	63	64	64	65	66	67	68	69
3800	61	61	62	62	63	63	64	65	65	66	67	68	69	70
4800	62	62	63	63	64	64	65	66	66	67	68	69	70	71
6000	63	63	64	64	65	65	66	67	67	68	69	70	71	72
7440	64	64	65	65	66	66	67	68	68	69	70	71	72	73
9600	65	65	66	66	67	67	68	69	69	70	71	72	73	74
12000	66	66	67	67	68	68	69	70	70	71	72	73	74	75
15000	67	67	68	68	69	69	70	71	71	72	73	74	75	76
19000	68	68	69	69	70	70	71	72	72	73	74	75	76	77
24000	69	69	70	70	71	71	72	73	73	74	75	76	77	78
30000	70	70	71	71	72	72	73	74	74	75	76	77	78	79
36000	71	71	72	72	73	73	74	75	75	76	77	78	79	80
48000	72	72	73	73	74	74	75	76	76	77	78	79	80	81
60000	73	73	74	74	75	75	76	77	77	78	79	80	81	82
74000	74	74	75	75	76	76	77	78	78	79	80	81	82	83
96000	75	75	76	76	77	77	78	79	79	80	81	82	83	84
120000	76	76	77	77	78	78	79	80	80	81	82	83	84	85
150000	77	77	78	78	79	79	80	81	81	82	83	84	85	86
192000	78	78	79	79	80	80	81	82	82	83	84	85	86	87
240000	79	79	80	80	81	81	82	83	83	84	85	86	87	88

Note: Values in body of this table are A-weighted noise levels expressed in dB. *Source: Road and Rail Noise Effects on Housing, CMHC, 1977.*

Chapter 7 — Conclusions and Measures for Consideration

Conclusions

1. The evolution and the growth of use of the automobile are related closely to the historic growth of Canada and its developing urbanization. Approximately 8.9 million automobiles were registered in Canada in 1975 with more than 11 million Canadians holding a driver's licence. Eighty percent of all Canadian households owned one or more automobiles. Since 1950, the number of drivers has more than tripled, the number of registered autos has quadrupled, and car-owning households have nearly doubled.

In 1975, the automobile fleet travelled about 87 billion miles, more than five times the auto miles that had been travelled in 1950. Approximately 10% (8 billion miles) of this total was inter-city traffic, with the remainder split about 55% (51 billion) urban travel and 35% (28 billion) rural travel.

All Canadian households generate, on average, about 12,700 auto miles per year. In both urban and rural areas, commuting generates the most miles travelled by an average household, averaging about 38% of household miles per year. Nearly 90% of all the miles Canadian passengers travel domestically on all modes are in the automobile with the remainder split at about 3% on urban transit, 1.4% on inter-city bus, less than 1% on inter-city rail and nearly 5% on domestic aircraft.

In 1975, about 7 billion gallons of gasoline were required to propel the auto fleet, five times the amount of gasoline that had been consumed in 1950. Gasoline consumption by automobiles accounted for about 25% of total Canadian oil consumption.

By 1975, Canadians had about 137,000 miles of paved roads for their use, more than five times what had existed in 1950. Road expenditures rose from some $300 million in 1950 to about $3.8 billion in 1975.

In 1975, expenditures on auto use totalled about $13 billion. This cost can be broken down to an average of $1,460 per auto, $1,900 per household or about 15¢ per auto mile.

Of the 6,061 people who died on Canadian roads in 1975, nearly 5,000 (81%) lost their lives in accidents involving automobiles. The total yearly cost of auto accidents is estimated to be about $2.5 billion, including property damage of about $1.4 billion, lost work effort of an estimated $1 billion and health care of about $100 million. While fatal accidents cost an average of $150,000 each, including lost work effort, injury accidents cost an average of $6,000 each, and accidents only damaging property cost an average of $800 each. However, with the advent of more and better safety programs, regulated safety measures in automobile design and construction, better driver education and so on, the fatality rate per hundred million vehicle miles has been declining, from a peak of 8.7 in 1964, to 6.7 in 1973, and to 4.7 in 1976.

In the ten years between 1964 and 1974, total employment in the automobile and auto-parts manufacturing industry increased from 69,000 to 108,000. This industry contributed approximately 3% of the 1975 Canadian GNP. In recent years, imports from Europe, Japan and other countries have captured about 20% of the Canadian new car market.

Provincial road revenues from fuel taxes, registration fees, tolls, etc., from all vehicles covered only about 40% of the 1975 road costs of $4.8 billion. Nevertheless, the distribution of costs, traffic and revenues is such that urban road revenues more than cover urban infrastructure costs, revenues from major inter-city highways seem to cover their costs, and the rest of the road system appears to be in a deficit position. However, road revenues do not cover urban social costs related to congestion.

2. Oil is the major and most critical source of energy supply; both the automobile and other passenger modes use it almost exclusively as a source of fuels. During the period 1980-2000, the world outlook for oil indicates a possible shortfall in supply. The Canadian outlook for domestic demand and supply seems more favourable, provided that the tar sands and frontier areas perform as expected, or conventional supplies expand to compensate. Gaps between demand and domestic supply, heavy imports and physical shortages may appear in the 1980s. There is, however, a high degree of uncertainty associated with these predictions.

3. The most likely technological advancements are in further development of the conventional (Otto) engine, development of engines using either lesser refined or blended fuels, and the continued down-sizing of all vehicle classes. A specialized urban car also may be a future possibility. Although many promising alternative technologies and energy sources are being developed, competition from the conventional automobile is so great that significant alternatives are unlikely to appear in the market place in this century. Substitutes for personal travel, such as teleconferencing and home-oriented work centres, are unlikely to take the place of the automobile on a substantial scale in this century, although there is promising and rapid development in telecommunications and computerization.

4. In order to assess the possible alternative futures for the automobile on a broad scale, three basic scenarios, with associated demographic and economic parameters, were selected for study. These are low, normal, and high economic growth scenarios, with energy crisis and energy conserving variations on the normal growth theme. The low growth and the energy crisis scenarios may result in an increase of only about 30% in auto miles travelled (AMT) by end century; the medium and the energy conserving scenarios may have an increase of about 100% in AMT; the high growth scenario, an increase of about 150%. The energy crisis variation would result in a 40% drop in AMT in the 1980s, followed by a slow recovery. The automobile fleet and new car sales would expand correspondingly with these estimates of AMT. The actual average new car fuel economy would rise from about 19 m.p.g. in 1975 to about 35 m.p.g. for the low growth, 34 m.p.g. for the normal growth, and 33 m.p.g. for the high growth scenarios by end century. The actual fleet economy, estimated at 18.5 m.p.g. in 1975, would improve to between 30-32 m.p.g. by the year 2000, for the three scenarios. In the energy conserving and energy crisis variations, fleet fuel economy would rise to about 38 m.p.g. by end century.

It should be noted that Canadian average fuel consumption data are proving to be more optimistic in fact than is postulated by the scenarios. National average fuel consumption for the 1978 model year was better than the 1978 federal target, projected sales data suggest the 1979 target will also be exceeded, and there is little doubt that the Canadian fuel consumption objective of 33 m.p.g. in 1985 is technically feasible.

Total auto gasoline consumption would tend to stabilize at the 1975 level for the normal growth scenario. Consumption would fall for the low growth, energy crisis, and energy conserving scenarios. The high growth scenario, which assumes minimal energy supply problems, predicts a rise in gasoline consumption. Oil imports would tend to peak at about 1985 and decline thereafter.

Use of the transit and the inter-city bus modes would at least double by end-century. Rail use would stabilize under all scenarios except energy crisis, which would involve an increase in its use. Use of the air mode probably would double, at least, for all but the low growth scenario.

5. Most of the growth in households is expected to take place in urban areas, and most of the future increase in auto mileage will be generated there. The basic relationships between the

auto and urban transit show that transit is more cost-effective than the auto for congested core-oriented trips, while the auto is more cost-effective than transit for dispersed trips. However, the auto does not cover its full social costs. The integration of housing data with extensive recent data on travel to work in Canadian cities indicates that the major determinant of the average trip length to work is the average distance of dwellings from the Census Metropolitan Area (CMA) centres. Distribution of work places, and other factors, have little apparent effect on the average trip length to work.

Through analyzing and forecasting auto miles travelled (AMT) as a function of household and housing growth in the 22 CMAs, it is estimated that by end-century, auto mileages inside the CMAs would increase by about 115% in the low growth situation, by 133% for the normal growth scenario and by 176% for the high growth scenario. The major forecast increases in households and traffic will be in a few cities, primarily Toronto, Vancouver, Ottawa-Hull, Edmonton and Calgary. Transit use is mainly confined to the trip to work or core-oriented trips. With appropriate investment in mass transit systems in the high growth cities it could be expected to expand generally in step with auto mileage and roughly retain its market share. The most cost-effective mass transit mode is apparently the express bus on bus-ways, provided that capacity is available to handle the resultant central volumes of vehicles and passengers. Under certain circumstances, other transit modes such as guided systems, and buses operating on arterials could be more cost-effective than the auto mode or express buses on bus-ways.

Transit is generally more energy productive (in terms of passenger miles per gallon) than the urban automobile, but tends to lose this advantage with the spread of services and the lower load factors in off-peak hours. In view of the forecast growths in urban AMT, there still seems to be a cost-effective and energy saving case for peripheral (circumferential) highway investments to complement (not compete with) transit, without encouraging additional urban spread and auto use. In general, CMA auto trip to work speeds are high, approximately 27 m.p.h. Auto trips to work are carried out mainly under uncongested conditions where estimated fuel consumption per mile tends to be comparatively low although, without appropriate highway investments, these conditions could be expected to deteriorate.

6. For inter-city passenger transport, where the automobile has also achieved a dominant position (particularly for shorter trips), a comparison with other modes shows that it maintains its advantage only for short trips at low passenger volumes, e.g., up to 100 miles and up to 100 passengers per day. For medium passenger volumes above these and for trip lengths of up to about 400 miles, bus is potentially the most cost-effective mode, followed by air for longer trips and higher volumes and possibly modern rail for high volumes. However, since auto users do not seem to perceive the full costs of car operation, they tend to choose the auto over the bus for inter-city travel. The consequent relatively lower demand tends to inhibit the development of the bus mode to its full potential. Since the bus at present is by far the most energy productive inter-city mode in terms of passenger miles per gallon, it may be concluded that, by means of higher auto fuel taxes and prices, and more direct measures and experiments, there is a case for encouraging the further development of the inter-city bus for medium length trips and medium passenger volumes in response to energy concerns.

7. During the 1973-77 period, the total number of deaths and injuries, associated with automobile accidents, fell. This decrease was associated with increased use of seat belts, lower speed limits and federal and provincial safety programs. While this progress can be expected to secure further reductions in death and injury rates, increases in the absolute numbers of deaths and injuries for all scenarios (except perhaps low growth) are expected because of rising AMT. A future shift towards smaller automobiles and greater heterogeneity in the auto fleet might be expected to increase the average severity of accidents. This may be offset by less severe accidents to pedestrians and other more vulnerable vehicles, plus other factors. Accident costs (at about $2.5 billion) are a significant factor in the total cost of operating an automobile.

8. The maintenance of present (1975-80) new vehicle pollution control standards for hydrocarbons, carbon monoxide and nitrogen oxides could further reduce emissions up to about 1985, in spite of increases in urban traffic. However, with present standards, nitrogen oxide emissions may increase after 1985. Higher standards may be required for all pollutants toward the end of the century (depending on complex policy decisions and trade-offs between pollution, energy consumption and automobile costs) as the future in terms of energy, pollution, and urban traffic growth becomes clearer.

The noise impact of the forecast growth in auto miles travelled can be expected to increase slightly; however, noise problems could be stabilized by controlling noisier vehicles. Salting of highways, land absorption by the automobile, and urbanization, though modest quantitatively, are of some qualitative concern.

9. The automobile maintains a dominant and integrated position in Canadian life and it would be virtually impossible to displace it. The use of the automobile for inter-city travel has proven to be an effective way of moving people, particularly for shorter trips. While the bus mode is more energy efficient than the automobile and air travel is a quicker way to travel for longer trips, Canadians have made an emphatic statement about their preferences by choosing the automobile 9 times out of 10 for inter-city travel.

Similarly, for travel within urban areas, the auto is not as energy efficient, on the whole, as urban transit for core oriented trips, is more costly for the individual, and burdens the public with considerable social costs. Nevertheless, the majority of people on most occasions choose to use their automobiles for commuting, shopping, and other household travel.

Hence, the challenge of the next quarter century will be to improve the automobile's effectiveness in providing flexible, convenient, personal mobility; to decrease its negative urban effects; to increase its energy efficiency by down-sizing and improved fuel economy; and to further reduce auto related deaths and injuries.

Measures for Consideration

This study is mainly strategic and oriented to the provision of information. The complexities of jurisdiction make it difficult to propose detailed recommendations for policy or action, particularly as existing policies such as new auto fuel economy standards, and higher oil and gasoline prices, which have not yet had their full effect, may go a considerable way towards attaining a desirable future role for the automobile. With these reservations in mind, the following points are put forward for consideration:

1. Fuel Economy Guidelines

Fuel economy guidelines are suggested for the new automobile beyond the 1985 level (33 m.p.g.) to ensure that the automobile plays its full part in present and future national energy strategies by stabilizing total gasoline consumption in the face of rising automobile use, with contingency measures for enforcement if necessary.

2. Higher Oil and Gasoline Prices

Higher prices for oil and gasoline are reinforcing the fuel economy guidelines by making the output of new automobiles, which satisfy the new energy guidelines, more attractive to buy. The failure to call upon the automobile user to face the full cost of its use, including the social costs, no doubt leads to more miles being driven and therefore to the incurring of additional costs. These problems need to be both recognized and remedied.

3. Maximum Use and Provision of Transit in Urban Areas

Maximum use of transit, and its provision in urban areas are suggested, subject to the cost-effectiveness and and energy productivity of transit (in passenger miles per gallon) compared with the urban automobile. Maximum use would be aided by the greatest possible centralization of jobs, by limitations on radial highway investments, by reasonable subsidies, central parking charges, and staggered working hours. In addition, since taxis are used quite heavily by lower income groups and by the auto non-user, some liberalization of regulations and of entry into the industry might be considered where appropriate, together with van-pooling and other cost-effective and energy productive forms of para-transit.

4. Maximum Encouragement of the Inter-city Bus and Modern Rail (with high load factors)

Since the inter-city bus seems to be potentially the most cost-effective and energy productive public mode up to trip lengths of about 400 miles, its maximum use should be encouraged. Since bus use, particularly by higher income groups, does not seem to be very responsive to price (ref. 36), this could probably best be done by experiments in upgrading services (e.g., executive buses) and withdrawal of unprofitable competing modes and services, rather than by subsidy. To a lesser known extent, the same considerations would apply to modern rail at high load factors, but with rail being more attractive to the higher income user (ref. 36).

5. More Compact Urban Growth and Form

The evidence of the 1971 census and subsequent travel to work data has indicated that the location of residential dwellings in relation to city centres is the major determinant of urban trip lengths. More compact urban growth, in-filling, and higher density developments, with the objective of having dwellings located closer to city centres, seem to be indicated (subject to households' preferences for dwelling types, etc.). Closer integration between urban planning, housing and personal transport is suggested, with consideration of investments in circumferential highways for rapidly expanding metro areas.

6. Seat Belt Use and Enforcement of Lower Speed Limits

Increased seat belt use and lower speed limits appear to have been the most cost-effective ways of reducing deaths, accidents, and accident rates. It would appear, therefore, that use of seat belts should continue to be encouraged and that speed limit regulations should be enforced (particularly in rural conditions) together with the continuation of provincial highway safety measures.

7. Environmental Standards

Standards and measures to stabilize or reduce pollution, and monitoring of vehicle emissions and noise, in the face of rising vehicle mileage, particularly in urban areas, should be considered.

8. Data, Research, Development and Monitoring

There is an obvious need for further data, research, development, monitoring and co-ordination in all of the areas covered in this study. However, because of jurisdictional matters and potential overlap with many other agencies, the precise institutional mechanisms that might be used must be explored further. The major priorities for further study would seem to be in the areas of greatest uncertainty, e.g., energy, technology, the economy, and inter-city multi-modal issues.

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